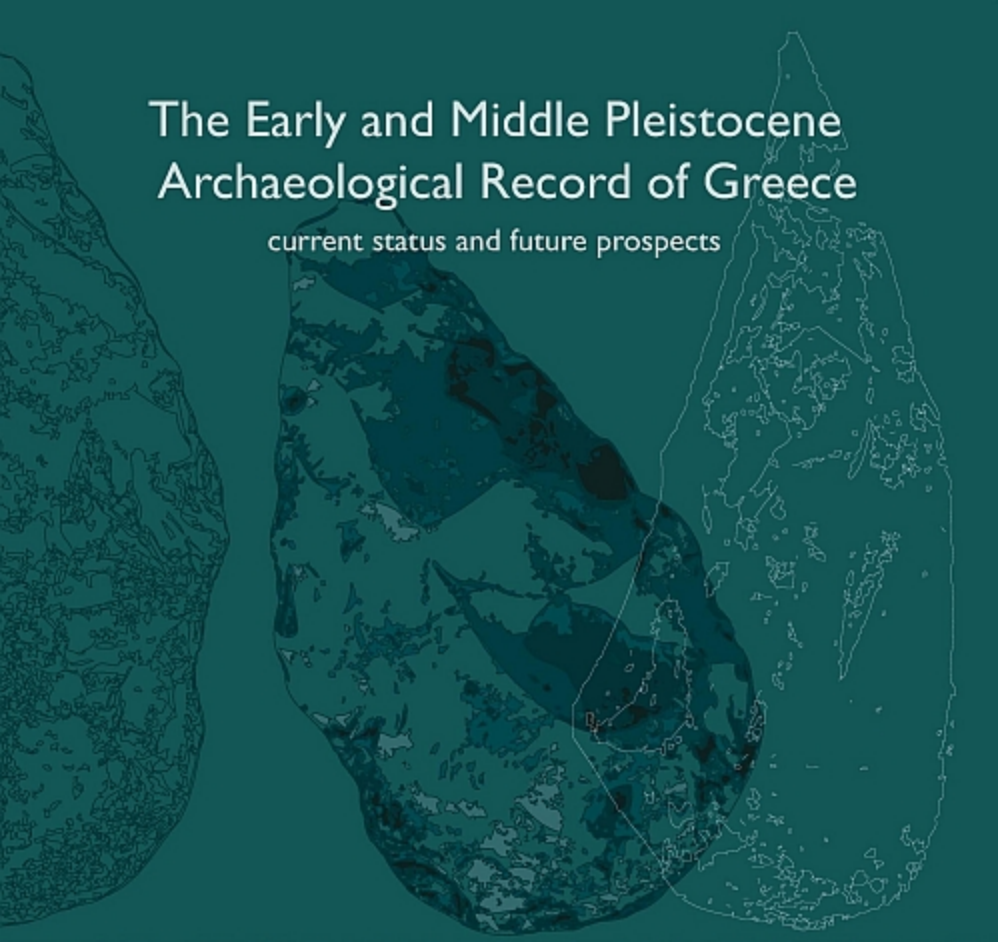




The Early and Middle Pleistocene Archaeological Record of Greece

current status and future prospects

Vangelis Tournloukis

ARCHAEOLOGICAL STUDIES LEIDEN UNIVERSITY 23

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Leiden University Press

Archaeological Studies Leiden University
is published by Leiden University Press, the Netherlands

Series editors: C.C. Bakels and H. Kamermans

Cover design: Joanne Porck

Lay out: JAPES, Amsterdam

Illustrations: Joanne Porck, Evangelos Tourloukis

ISBN 978 90 8728 106 9

e-ISBN 978 94 0060 026 3

NUR 682

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The Early and Middle Pleistocene Archaeological Record of Greece

Current Status and Future Prospects

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. P.F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 17 november 2010
klokke 13.45 uur

door

Evangelos Turloukis

geboren te Athene,
in 1976

Promotiecommissie

Promotor: prof. dr. W. Roebroeks

Overige Leden: dr. P. Karkanas
dr. E. Panagopoulou
prof. dr. C. Runnels
prof. dr. T. van Kolfschoten
prof. dr. J. Bintliff
dr. H. Kamermans

This research was made possible with a grant from State Scholarships Foundation (Greece).

στον πατέρα μου

Cos'è gementi schiavi
questo remar remare?
Meglio morir tra i flutti
sul biancheggiar del mare

Remiam finché la nave
si schianti sui frangenti
alte le rossonere
fra il sibilare dei venti!

(B. Pedrini, Il galeone)

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1 – Introduction

1.1 KEY RESEARCH QUESTIONS

The first -and so far the only- conference on the Palaeolithic of Greece was held in 1994 in Ioannina (Epirus, North-West Greece). In the publication of the proceedings (Bailey *et al.* 1999), only two out of thirty-four papers reported on Lower Palaeolithic finds from Greece, and these referred to the sites of Kokkinopilos in Epirus and Rodia in Thessaly (Runnels *et al.* 1999; Runnels and van Andel 1999). Since the first systematic investigations of the Palaeolithic in Greece in the early 1960's and up to around the times of the Ioannina conference, the evidence for a human presence in Greece before the Late Pleistocene was essentially restricted to the hominin crania from the caves of Petralona and Apidima and an undated handaxe that was considered to be of Lower Palaeolithic age by virtue of its Acheulean morphology. In 2009, almost five decades after the discovery of the Petralona fossil, and fifteen years after that conference, the only sites pre-dating the Late Pleistocene in Harvati and colleagues' table with 'Important Palaeolithic Sites in Greece' (2009, 132) are still the same: Petralona, Kokkinopilos and Rodia.

This picture is partly the result of extremely biased research objectives that have been prevailing since the establishment of the Greek state in the early 19th century. In constructing the notion of Greece being the 'cradle of Western civilization' and with the local middle class building its ascendancy and its position in a progressively integrated Western World, nationalist policies have been directing research designs towards the unraveling of the 'glorious past' of the Classical Period and the Bronze Age civilizations of the Aegean (Kotsakis 1991; Galanidou 1996). Nonetheless, the geographic position of Greece forced scholars to acknowledge its potentially crucial role as a gateway to Europe, with regard to three major subjects in prehistory: the origins and spread of agri-

culture in the early Holocene, the peopling of Europe by *Homo sapiens* in the Late Pleistocene, and the earliest dispersals of hominins into and within Eurasia in the Early and Middle Pleistocene (*e.g.* Runnels 1995). It is the latter topic that is of direct interest here, and Greece has been for long expected to contribute valuable evidence for the earliest occupation of Europe, because of three main reasons: (1) it lies within the most probable route facilitating hominin movements between Africa and Eurasia and vice versa (*e.g.* Harvati *et al.* 2009), but also in a longitudinal axis within Eurasia itself (2) due to its Mediterranean climate and highly productive ecozones, it is assumed that it would have served as a refugium area for floral, faunal and hence probably also human populations, during the harsh climatic conditions of glacial spells (*e.g.* Hewitt 2000) (3) on current evidence, the Mediterranean part of Europe appears to have been peopled earlier than the rest of the continent north of the Alps (*e.g.* Roebroeks 2006).

In the circum-Mediterranean region, the rich records of the Iberian and Italian peninsulas, the early sites in North Africa and the Levant, and the growing evidence coming from Turkey and, lately, some of the northern Balkan regions as well, altogether furnish a pattern of early Pleistocene human geography in which Greece stands out as a conspicuous lacuna. Consequently, the question that emerges, and constitutes the key research query in this study, is how are we to explain the absence of Early and paucity of Middle Pleistocene sites in Greece? There are three main parameters to consider in answering this question: (1) research intensity and biases (2) the possibility that we are dealing with a marginal / episodic / intermittent occupation which left poor and/or hardly detectable traces, and (3) the possibility that the geological history and structure of a dynamic landscape has been disfavoring the preservation of archaeological remains. The research-intensity argument is cer-

tainly an issue, but it cannot sufficiently explain the paucity of sites: for example, as it is discussed below (4.5.5), the abundance of Palaeolithic material in areas such as Epirus can no longer be accredited to the lack of fieldwork elsewhere (Runnels and van Andel 2003, 125). The current state of the record testifies only to a general assertion about human *presence* in the Middle Pleistocene; Lower Palaeolithic *occupation* in Greece is yet to be established, and, until then, there is hardly anything to say about the nature of this occupation, let alone to test if an intermittent/episodic character could account for the patchiness of the record. Therefore, to explain this patchiness, it is most meaningful to explore the geological structure of the landscape and the potentially biasing effects of geomorphic processes that have been at work throughout the Quaternary.

It has been assumed that “the Quaternary in Greece has mostly been a time of erosion” (van Andel 1998, 376), and that “there is reason not to expect a very complete record in a country as mountainous as Greece” (Gowlett 1999, 43). Similar assumptions have often appeared in the literature, but only in a somewhat anecdotal form. This study evaluates such statements by using both empirical data from fieldwork observations and more theoretical assertions that can be deduced from relevant geomorphological studies. In this line, there are two additional, interrelated research questions that are examined here:

1. To what degree should we expect Lower Palaeolithic material to be not only preserved, but also archaeologically visible/accessible, according to the directions provided by the study of the geology and geomorphology?
2. Where should we eventually look for Lower Palaeolithic evidence?

Various scholars have pointed out that Greece will, sooner or later, most likely yield early Palaeolithic sites (*e.g.* Runnels 1995; Dennell and Roebroeks 1996; Gowlett 1999; Roebroeks 2001), whilst some have stressed the ever-growing state of research, suggesting that the Greek record “is already of real importance in assessing the nature of early colonization of Europe” (Gowlett 1999, 54). However, Greece is still lacking the kind of evidence which would be quantitatively and qualitatively comparable to that coming from the rest of the Mediterranean. Explaining

this discrepancy will reveal directions towards reversing this picture and putting Greece on the map of early Palaeolithic sites. In short, to assess why the record is so poor; how much of it may have been lost or rendered archaeologically inaccessible due to erosion/deposition; what should we actually expect from Greece to yield; and, last but not least, where should we look for it -all these questions are difficult to test in a spatial scale of more than a hundred thousand square kilometers and a temporal scale of almost two and half millions of years. Geomorphic processes cannot be modeled in such scales. However, attacking those questions can still be meaningful, and it shows how valuable information can be extracted from a record with an extremely fragmented and biased profile.

1.2 SCOPE, OBJECTIVES AND STRUCTURE OF THE BOOK

In terms of a temporal range, my study examines the Early and Middle Pleistocene record of Greece. This time-frame is taken here to match what in archaeological terms is traditionally denoted as the Lower Palaeolithic period, an assertion that is justified and discussed in more detail below (section 2.1). ‘Greece’ obviously stands for a political entity and, as such, it is at odds with the fact that, in Palaeolithic studies, areas targeted for investigations are usually delineated with reference to (bio-) geographical and/or geomorphological boundaries. The political territory of Greece was therefore chosen for convenience, *e.g.* with regard to administrative issues and research permits for doing fieldwork. Moreover, the political boundaries of Greece essentially correspond to the geographical limits of the peninsula that projects southwards from the Balkans, allowing comparisons with the other two Mediterranean peninsulas, *i.e.* the Italian and the Iberian, which have yielded the richest Lower Palaeolithic records.

This research is partly fieldwork- and partly literature-based, and has three main objectives. Firstly, to provide a critical re-appraisal of all sites, findspots and isolated artefacts from Greece that have been attributed to the Lower Palaeolithic period. Similar, but more coarse-grained evaluations have been presented with regard to the entire Palaeolithic and Mesolithic record of Greece as a whole (Runnels 1995), the

Pleistocene palaeoanthropological and archaeological records of Greece (Harvati *et al.* 2009), or the record of the Middle Palaeolithic (Daras 2007); up to now, the literature lacks a thorough assessment of the Greek ‘Lower Palaeolithic’ evidence in its own right. To this end, the focus is put on the artefactual material, its depositional setting, any associated dating and the argumentation for ascribing it to the Lower Palaeolithic. However, in order to facilitate comparisons with other archaeological records of the Early and Middle Pleistocene, a framework of reference is needed. This is provided in chapter three, where the best-studied Lower Palaeolithic sites of the circum-Mediterranean region are reviewed with a special attention to their geomorphological environments, depositional contexts and dating. Together with chapter two, which outlines the main aspects of the Lower Palaeolithic period and of the hominin dispersals occurring during this time-span, the examination of the circum-Mediterranean records sets the background for juxtapositions with the picture emerging from Greece; moreover, it allows the Greek evidence to be viewed within the perspective of the debate about the earliest peopling of Europe.

Considering that the nature and completeness of the archaeological record is furnished in concert with the nature and completeness of the geological archive, the second part of the thesis explores the geological factors which obscure preservation of material and filter archaeological visibility and accessibility. The investigation starts with chapter five, which contextualizes the results from fieldwork that I have conducted in the frames of two survey projects in Macedonia and Zakynthos. Here, the absence of stratified Lower Palaeolithic material is assessed, thereby bridging the previous evaluation of the Greek evidence-at-hand (where it is shown that stratified material is overall scarce) with the next and final part of this study. Thus, chapter six explores the Quaternary landscape evolution in Greece and aspires to fulfill the other major goal of this research, namely to explain the scantiness of the Greek testimony under a geoarchaeological perspective. Climatic, tectonic, sea-level controls and surface processes are considered in order to comprehend their interactions and their effects upon the integrity of the archaeological record. In construing the results of this exploration, I use a GIS-based slope-map of Greece, which serves

as a visual platform for discussing the major conclusions.

Finally, chapter seven offers a synthesis of the results from all previous chapters. Compared to any general patterns deduced from the circum-Mediterranean evidence, how does the Greek Lower Palaeolithic material fit in the debate about the earliest occupation of Europe? Is there any solid evidence for an Early Pleistocene human presence in the Greek Peninsula? Is it meaningful to make any inferences about the first indications from Greece with regard to lithic techno-complexes (*e.g.* Mode I versus Mode II) and how these should be interpreted when juxtaposed to general trends identified in the rest of the Mediterranean? Which are the dominant geomorphological settings with which the Greek sites are associated, how do we evaluate this association, and, what is more, is it possible to distinguish hominin preferences from preservation biases? Possible answers to those questions are discussed in this final chapter. The emphasis, though, is above all given to the answering of the major research questions as outlined previously: how do we understand the paucity of the record, what should we eventually expect from Greece to yield in the future and where should we concentrate our investigations.

In his 1995 review of Aegean Prehistory, C. Runnels writes (p. 709): “The increased rate of discovery of Lower Palaeolithic sites has been made possible by our growing understanding of Pleistocene deposits and their associated geological features, permitting us to pinpoint the places where archaeological materials of a particular age are likely to be best preserved...” Following this suggestion, my research examines the geological opportunities that have been available throughout the Quaternary, determining the qualitative and quantitative characteristics of the geoarchaeological archive and the degree in which this is preserved and accessible in the present. In turn, this examination serves best a dual objective: to understand and explain the current status of the Greek evidence, also by viewing it in the context of the earliest occupation of Europe; and to put the Lower Palaeolithic of Greece in prospect, by providing first-order directions for future investigations. As a geoarchaeological approach to a biased and much fragmented record, it is argued that the results and

suggestions proposed here can potentially be seen as being of wider significance, going beyond the tem-

poral range of the Lower Palaeolithic and the spatial limits of the Greek peninsula.

2 – Lower Palaeolithic archaeology and the peopling of Europe

2.1 THE LOWER PALAEOLITHIC PERIOD: AN INTRODUCTION

According to the traditional division of the Palaeolithic, the period discussed in this study is called the Lower Palaeolithic and its lower limit is anchored to the appearance of the earliest manifestations of human culture. The latter proposition is burdened with problems in the definition of each one of its components: the adjective ‘earliest’ refers to a floating chronological bracket; ‘human culture’ is difficult to define, because both concepts are identified on the basis of criteria that may be characterizing other species as well; whilst ‘manifestation’ also depends on how the former two terms (human and culture) are outlined and how much detectable they are in archaeological terms. That being said, what is commonly considered as the oldest known evidence of hominin stone-tool technology and possible carnivory appears at around 2.6 Ma in Africa, where clusters of lithic artefacts (see below) were found together with animal bones (Semaw *et al.* 2003). The first members of *Homo* are generally thought to have emerged around this time, which is effectively regarded as the onset of the Lower Palaeolithic (*e.g.* Klein 2009). However, we do not know exactly which species is responsible for the first stone-tool manufacture, because during the earliest part of the Early Pleistocene, probably more than two hominin genera and six species were present in Africa (*e.g.* Wood and Collard 1999). In fact, not only it is difficult to prove that *Homo* was the only tool-making genus at that time, but also the conventional criteria for assigning a species to the *Homo* genus (*e.g.* human-like precision grip and tool-making ability, brain size and ‘language’) are now deemed unsatisfactory (*ibid.*). Such issues remain unsettled and highly controversial (*e.g.* Cela-Conde and Ayala 2003; Tattersall and Schwartz 2009), but are not of primary concern here. Thus, in

line with the prevailing view, I consider the datum of 2.6/2.5 Ma as the lower boundary of the Lower Palaeolithic period.

On the current evidence, we assume that it was at around the beginning of the Pleistocene (*i.e.* at *ca.* 2.5 Ma; for the Pliocene-Pleistocene boundary see below) when members of the *Homo* lineage developed larger crania and brains, incorporated a more carnivorous diet and produced an archaeologically visible material culture. The latter is exemplified by the Oldowan lithic industry and consists of crude and informal artefacts, including simple flakes, cores, bifacial choppers, chopping-tools and scrapers. While this industrial complex persisted for more than a million years, it was at *ca.* 1.8 Ma that the first hominin species with a more human-like body form enters the scene, also carrying with it (from *ca.* 1.5 Ma onwards) a more refined tool-kit, the Acheulean Industrial Complex, consisting of bifacially worked tools such as handaxes, cleavers and picks (*e.g.* Clark 1994; Klein 2000). This hominin, known as *H. ergaster* (for the African variants) and/or *H. erectus* (*sensu lato*, or *sensu stricto* for the Asian types) is the earliest one that meets all of Wood and Collard’s (1999) criteria for a membership in the genus *Homo*, and it has for long been considered as the first one capable of migrating out of Africa and into Eurasia (but see below). Long-lasting controversy surrounds the morphological variability in fossils included within the *H. ergaster* / *H. erectus* hypodigm(s), and *H. ergaster* remains until today “absolutely without precedent” (Tattersall and Schwartz 2009, 74). Nonetheless, some European specimens that were once classified as (late) *H. erectus* are now considered to belong to *H. heidelbergensis*, the species that appears in Africa and western Eurasia in the first half of the Middle Pleistocene. Again, it is not clear when or where exactly *H. heidelbergensis* first appeared and

what is its phylogenetic relationship with earlier, penecontemporaneous and later hominins; for a long time, numerous specimens that retain some more primitive (*erectus*-like) features but also share a number of derived ones with modern humans, have been referred to as ‘archaic *H. sapiens*’, a term that has been lately replaced by the revived nomen *H. heidelbergensis*. Some researchers see *H. heidelbergensis* as an Afro-European species giving rise to both Neanderthals and modern humans; others consider it as an exclusively Eurasian chronospecies ancestral to Neanderthals while another, African form (*H. rhodesiensis*) led to modern humans; there is also the view that there can be no clear divide between *H. heidelbergensis* and *H. neanderthalensis* (e.g. Hublin 2009 and references therein; Mounier *et al.* 2009). A newly proposed species, *H. antecessor*, was initially seen as the common ancestor of Neanderthals and modern humans, and/or as an antecedent of *H. heidelbergensis*, but lately it is suggested that it represents a European lineage different from other African and Asian ones, perhaps not leading to Neanderthals (e.g. Carbonell *et al.* 2005; Bermudez de Castro *et al.* 2008). However, it might equally represent an unsuccessful dispersal event into Europe (Tattersall and Schwartz 2009).

Whichever hominins were involved in the earliest incursions into Europe, it appears that biological and cultural innovations need not occur in phase. In the European Middle Pleistocene, there is a great morphological variation reflected in fossil specimens, and a complex set of cultural variability mirrored in lithic assemblages; temporal and spatial discontinuity in the records obstruct correlations between certain species and specific lithic complexes. Alternatively, important cultural advances that are introduced during the Middle Pleistocene may in the future prove to be associated with a hominin form, which on the current terminology would be included within *H. heidelbergensis* (*sensu lato*). Besides exceptions of controversial status such as *H. cepranensis*, named after a calvarium that was found at Ceprano, Italy (lately dated to *ca.* 0.45 Ma; Mallegni 2006; Muttoni *et al.* 2009); and excluding (undetermined) fossils referring to ‘ante’-, ‘early’ or ‘pre-Neanderthals’, *H. heidelbergensis* is the most commonly identified species in Europe for the time-span between *ca.* 600–200 ka. Without implying any conclusive linking, it is note-

worthy that the ‘Middle Pleistocene Transition’, marking a change in the amplitude and length of the glacial-interglacial cycles (Head and Gibbard 2005; see section 6.2), is centered close to the time when *H. heidelbergensis* first appears in the European landscapes (*ca.* 600 ka at Sima de los Huesos). After about 500 ka, the archaeological record becomes more substantiated, compared to the pre-500 ka periods. It is also around this time that the second major expansion of the brain is observed in hominins, when brain size increased to its modern level (e.g. Aiello and Wheeler 1995). Similarly, it is with *H. heidelbergensis* that body size and body mass enter the range of modern *H. sapiens*, which could be suggesting that the evolution of modern-like life history began essentially at this point in the human lineage (Dubreuil 2010; *cf.* Aiello and Dunbar 1993). Furthermore, after this critical datum of *ca.* 500 ka, we begin to find more solid (albeit not always uncontested) evidence for some important aspects of hominin social life: hunting, manipulation of fire, cooking, as well as possible forms of dwelling structures (e.g. Thieme 1997; Preece *et al.* 2006; Carmody and Wrangham 2009; *cf.* McNabb 2007, 346–373). The oldest-known examples of the Acheulean industrial complex appear in Europe around this time-line, too (but see Villa 2001 and Scott and Gibert 2009). Although *H. heidelbergensis* was perhaps as much culture-dependent as its alleged predecessor (*H. ergaster*), I agree with McNabb (2005) that they both used the tool-making component of their material culture in processing activities mostly; their success in colonizing new areas was likely based on biological and behavioral attributes other than technological dependency. For instance, using the aforementioned evidence for biological/cultural innovations (brain growth, hunting and use of fire) Dubreuil argues that *H. heidelbergensis* was engaged in riskier and longer-term cooperative goals than earlier hominins in the domains of feeding and breeding; and that “this change was made possible by the presence of a modern-like capacity on the part of the individuals to assess the risks of cooperation and to stick to cooperative arrangements” (2010, 55). In studies like the latter, the argumentation is in varying degrees inferential and not directly verifiable upon the archaeological record. But when they are complementary to other lines of evidence, such studies can offer valuable alternatives to long-lasting problems: for in-

stance, the thorny issue of cultural periodizations and the question of how solid definitions of periods are, when they are chiefly based on lithic typo-technological criteria.

Distinguishing cultural periods in (pre)history is essentially inescapable and it has been habitually grounded on the identification of transitions separating certain time-blocks. Transitions are artificial constructs that are used to structure the study of the past and facilitate inter- and intra-disciplinary communication between scholars; as soon as transitions and periodizations are perceived as consolidated ‘realities’, immune to reassessments, their function as analytical tools is cancelled and even reversed (*cf.* Roebroeks and Corbey 2001). It is thus understandable that, following earlier suggestions, some scholars prefer to use the term ‘Early Palaeolithic’ to include both the Lower and the Middle Palaeolithic period (*e.g.* Runnels and van Andel 2003). Traditionally, the Lower/Middle Palaeolithic boundary is set at around 300 ka and is marked by the appearance of the Levallois technique. Recently, Monnier (2006) described in detail how the staging of the European Palaeolithic has been historically based on the use of a *fossil directeur* approach; she shows that from the very beginning, with de Mortillet’s classification, up to the Bordesian typological scheme and the subsequent technological methodologies, the Lower and Middle Palaeolithic stages have been set apart according to the presence/absence of lithic ‘index fossils’, namely bifaces and Levallois products, the latter usually included in flake-tool-based industries. Monnier analyzed 89 assemblages from 26 radiometrically-dated sites of Western Europe, spanning OIS 17 to 3. Her results showed that although there is a significant drop in biface frequency from OIS 9 to 8, bifaces do not disappear, hence they are useless as chronological markers; Levallois technology is almost entirely absent until OIS 8, becoming full-blown only in OIS 6. In construing her data, Monnier states that “the appearance of Levallois technology *could* be used to distinguish the Lower from the Middle Palaeolithic, but then this boundary would have to be moved to the beginning of OIS 6 or somewhere within OIS 7, when Levallois technology becomes numerically significant” (*ibid.*, 729).

As implied in the title and stated in the introduction, my examination of the Greek record focuses more on stratigraphically-supported arguments and less on typological ascriptions. In this view, I consider the beginning of the Late Pleistocene as the upper limit for the record under study. The choice of this datum is largely arbitrary, but it is supported by the fact that, on the current evidence, the oldest-known so far dated Greek Middle Palaeolithic site and/or the earliest appearance of the Levallois technique in Greece is placed around *ca.* 130 ka and most probably within the time-span of the last interglacial period (at Theopetra Cave; see 4.1; Valladas *et al.* 2007). Consequently, at least for the time being, this limit can be overall regarded as a culture-stratigraphic boundary. Opting for the presence of the Levallois method as an assistive tool in discerning here the onset of the Middle Palaeolithic has two practical advantages. Firstly, it is in line with most current views for the commencement of the Middle Palaeolithic in both the Mediterranean and the rest of Europe (*e.g.* Roebroeks and Tuffreau 1999; Mussi 2001; White and Ashton 2003); as such, it allows the exclusion of what is currently conceived as the Greek Middle Palaeolithic record, which, if included, would disorientate the scope of this research; additionally, it also allows the results of this study to be comparable with evidence from other Lower Palaeolithic records. Secondly, due to practical constraints and because this is not part of my research objectives, an assessment of the Lower/Middle Palaeolithic periodization in Greece could not be elaborated here.

Yet, there are many drawbacks in using the Levallois technique for such a purpose. For the definition, identification and interpretation of the Levallois technique, the reader is referred to Chazan (1997) and White and Ashton (2003), whilst Bar-Yosef and Van Peer (2009) provide a recent critique on and review of the methodological and epistemological problems in typo-technological systematics. Here, suffice to acknowledge the following points:

1. the appearance of the Levallois technique has most likely been temporally gradual and spatially discontinuous, depending on geographical and geomorphological settings (among many other factors)

2. artefacts with Levallois morphology can be made with multiple methods and not necessarily on a Levallois core (*e.g.* Chazan 1997)¹
3. the discreteness of the Levallois method from the discoid method has been questioned, and it has to account for the fact that
4. the morphology of a core reflects the last stage of the core's reduction sequence; in effect,
5. identifying the presence/absence of the Levallois technique requires an adequate sample, in which at least cores will not be underrepresented -a situation that is hardly met and/or barely demonstrable in the case of surface collections.

These Levallois-pitfalls are anticipated here. However, it should be noted that if the nature and meaning of a Lower/Middle Palaeolithic dichotomy is to be re-assessed, caution should be taken before downgrading the importance of the development of prepared-core-technologies. The Levallois technique incorporates the conceptual and practical fusion of two basic reduction methods, *façonnage* and *débitage*, which were practiced in the Lower Palaeolithic as separate, alternative strategies (White and Ashton 2003); the fusion of these two distinct operational systems has been called 'the incorporation of difference' (Hopkinson 2007). According to Hopkinson (*ibid*) this incorporation develops in Europe from *ca.* 200 ka onwards and coincides with the onset of systematic occupation of high-relief upland regions; together, these advancements signal behavioral and cognitive evolutionary changes. Interestingly, whilst Hopkinson focuses more on eco-geographical factors, such as spatio-temporal resource proximity, landscape structure and seasonality, he arrives at the same conclusion as Monnier (2006) in suggesting the datum of *ca.* 200 ka for the Lower/Middle Palaeolithic boundary.

1. For instance, in their analysis of the Dmanisi material, Baena *et al.* (2010) comment on cores with a more complex organization of the scars and note the following: "From a typological view of their morphologies, those could be considered as discoid cores or even levallois. On the contrary, a detailed analysis with a diachritical study shows that those are not generated with a levallois method (as understood by Boëda, 1993), even if their volumetric structure looks similar."

In sum, considering all the above (*i.e.* the practical limitations within the scope of this research, and the debate around the Lower/Middle Palaeolithic boundary), the archaeological evidence examined here involves the time-period between 2.58 to 0.126 Ma, namely the Early and Middle Pleistocene (see below). For the current purposes, this time-block is taken to represent what is conventionally called the Lower Palaeolithic period. Although the datum of ~200 ka is considered here as a (provisionally) justifiable datum-line for the Lower/Middle Palaeolithic boundary, I prefer to place the latter slightly later, at *ca.* 126 ka, *i.e.* at the beginning of the last interglacial, because it matches both the archaeological testimony at hand (earliest-dated Middle Palaeolithic site in Greece) and the geological consensus for the beginning of the Late Pleistocene. Finally, it is also noted here in brief that on the basis of technological, behavioral and cognitive indications from the European records, the period between *ca.* 400-200 ka is expected to be a reasonable candidate as the transitional phase between the Lower and the Middle Palaeolithic of Greece.

As a final note, it should be mentioned that the base of the Quaternary Period and the Pleistocene Epoch has recently been lowered to 2.58 Ma, to be coincident with the base of the Gelasian Age. The ratification of the proposal for a revision of the base-Quaternary boundary was published on June 30th 2009 (the official announcement can be found at www.stratigraphy.org), that is, when this book was reaching its final form. As a consequence, both the works of others that are cited here and my own assessments should be treated with reference to the previously defined Pliocene-Pleistocene boundary at 1.8 Ma, unless a reference to the new boundary is explicitly stated. This revision has important implications, *e.g.* regarding the vague term 'Plio-Pleistocene' and the Villafranchian mammal stage, but it was not possible to resolve such issues here. On the positive side, the revised boundary matches not only the earliest-dated stone-tool assemblage in Africa, but also the first significant changes in the climate system and the associated biotic responses. It has been suggested that those major global changes may have had fundamental impacts on human evolution, perhaps also triggering and/or facilitating the earliest human dis-

persals –a topic that is overviewed in the next chapter.

2.2 EARLY DISPERSALS AND THE FIRST OCCUPATION OF EUROPE

Due to the difficulty in identifying push- and pull-factors or distinguishing prime drivers, the earliest human dispersals within the Old World have been interpreted on the basis of various competing or converging hypotheses, which are often interrelated and integrate multi-disciplinary investigations. With only few exceptions challenging the consolidated paradigm of Africa being the cradle of humankind (e.g. Dennell and Roebroeks 2005), different causes and constraining/facilitating parameters underlying hominin range expansions have been addressed.

From *ca.* 2.5 Ma, the build-up of continental ice-sheets signifies the onset of the Quaternary glacial-interglacial cycles, with considerable implications on human evolution. Shifts to more arid conditions at 2.8, 1.7 and 1.0 Ma have been for long thought to have conditioned the emergence of bipedal, large-bodied hominins by creating new environmental niches; however, recent studies show that those key temporal junctures are linked with extreme climate variability on high moisture levels (Trauth *et al.* 2009). Alternatively, some researchers argue that climatic deterioration impeded human expansion into Europe: the first European settlement was possible only under mild climatic conditions, whilst physiography or cultural factors were of secondary importance (Agusti *et al.* 2009). In a stepping-out-of-Africa simulation, the late arrival of hominins in Europe (around 1.0 Ma; see below) is explained by mid-latitude vegetation being a barrier that led to the formation of scattered populations; in this model, the role of vegetation and the hominin ecological niche are highlighted (Hughes *et al.* 2007a). Other researchers focus more on ‘culture-specific’ aspects, such as hominin social life (e.g. Gamble 1999), or associations of dispersal events with certain technical (lithic) systems (e.g. Carbonell *et al.* 1999); whilst others prefer more holistic perspectives, combining biological relationships (body size, brain size, thermoregulation, diet shift to increasing carnivory, life history factors) with ecological and biogeographical approaches (e.g. Roebroeks 2001, 2006). The subject is obviously too

complex to be reviewed here (see e.g. Rolland 2010 for a recent overview), so the focus will be on three main issues, as the most relevant to the potential role of Greece in this debate: chronological frameworks, the archaeological patterning (spatio-temporal distribution of sites, continuity of occupation, dispersal routes), and taphonomic/preservation biases.

Currently, the earliest known and best-studied site in Eurasia is Dmanisi in Georgia, dated to *ca.* 1.8 Ma (Fig. 2.1); it has provided a morphologically variable hominin fossil material, which falls between *Australopithecus* and *H. habilis* on one hand and *H. ergaster* and *H. erectus* on the other (Martínón-Torres *et al.* 2008), or is even attributable to a new species (*H. georgicus*; Gabunia *et al.* 2002), and is associated with a Mode I (‘Oldowan-like’) lithic assemblage (Baena *et al.* 2010). In Europe, the oldest direct evidence for a human presence is attested at Sima del Elefante (Atapuerca, Spain) by fossils possibly representing the precursors of *H. antecessor* (perhaps signaling a speciation event), again associated with a core-and-flake lithic industry, and dated to *ca.* 1.2–1.1 Ma (Carbonell *et al.* 2008). Barranco Leon and Fuente Nueva, located also in the Iberian Peninsula, have yielded Mode I assemblages dating to *ca.* 1.4–1.2 Ma, whilst ‘Ubeidiya in the Levant dates to *ca.* 1.5 Ma (see chapter 3). If we exclude the Asian record from this consideration (e.g. see Dennell 2003), it is only the above five sites that provide solid and well-dated artefactual and/or fossil evidence for a human occupation of Europe and its periphery before *ca.* 1.0 Ma. And yet, based on this sparse evidence, or, even worse, on sites with a doubtful archaeological testimony or inconclusive datings, some scholars have suggested that at least two (Carbonell *et al.* 1999) or three (Bar-Yosef and Belfer-Cohen 2001) distinct waves of migrations are identifiable in the record; in these scenarios, Mode I (core-and-flake) and Mode II (Acheulean) assemblages are associated with different groups of hominins performing the technologically-culturally discernible, successive dispersal events. This view, and especially the association of lithic complexes with specific phylogenetic groups, has been convincingly disproved (e.g. Villa 2001; McNabb 2007). Moreover, genetic evidence indicates at least three major expansions out of Africa (Templeton 2002).



Fig. 2.1 Key Lower Palaeolithic sites of the circum-Mediterranean region and possible routes of early dispersals. Sites: 1) Dmanisi 2) Yarımburgaz 3) Dursunlu 4) Kaletepe Deresi 5) Karain 6) Kozarnika 7) Monte Poggiolo 8) Isernia 9) Notarchirico 10) Atapuerca sites (Trinchera Dolina, Sima del Elefante, Sima de los Huesos) 11) Torralba and Ambrona 12) Orce sites (Fuente Nueva 3, Barranco León) 13) Sites in the Casablanca area (Thomas Quarry I, Grotte des Rhinocéros) 14) Ain Hanech and El-Kherba 15) 'Ubeidiya and Gesher Benot Ya'aqov

Whereas the circum-European record becomes slightly enriched at around 1.0 Ma, it is only in the Middle Pleistocene and most notably from its middle part onwards, that it is significantly substantiated, both quantitatively and qualitatively: in marked contrast to the preceding period, after *ca.* 600/500 ka the European evidence is characterized by larger collections of lithic material (often conjoinable and from 'knapping floors'), more primary-context sites, more uncontested artefactual assemblages, and more human remains (Roebroeks and van Kolfschoten 1994). This sort of threshold most probably indicates "repeated, short-lived and modest dispersal events, rather than continuous residence" before *ca.* 600 ka (almost certainly so before 1.0 Ma: Dennell 2003, 434), with a more continuous presence becoming evident only after this datum-line. As this pattern cannot be discussed here (see *e.g.* Roebroeks 2006), suffice it to recall that the aforementioned 'threshold'² largely coincides with the mid-Pleistocene

(climatic) transition and it may be reflecting biological and behavioral traits linked with *H. heidelbergensis*; in that sense, it is the latter species, and not *H. erectus*, that could be characterized as a successful colonizer, or 'the earliest cosmopolitan hominid species' (Tattersal and Schwartz 2009; *cf.* Dennell 2003). 'Success' and 'continuity', however, retain their relativity as archaeologically discernible realities also after 600 ka, as the discontinuous nature of the Italian Early-early Middle Pleistocene record vividly shows (Villa 2001; see below 3.2). Considering this palimpsest of intermittent early dispersal events, the scarcity of sites in the period separating Dmanisi (1.8 Ma) from Atapuerca TD6 (0.8 Ma) is most likely reflecting hominin incursions that failed to attain a more permanent character (*cf.* Dennell 2003). Perhaps it was only after 'Atapuerca times' and especially after *ca.* 600 ka that colonization attempts were successful and/or gained an archaeologically visible demographic momentum, which would in

2. The quotations denote that the word threshold is used here only as a heuristically meaningful temporal line that helps us to grasp the wider patterns; suffice to mention that initially the 'threshold' was put at 500 ka, it was subsequently moved to 600/

500 ka, and lately it has been suggested to go a little more further back at 650 (McNabb 2005). Viewed in the time-frames of the Pleistocene, such differences of 100-150 ka do not change significantly the message coming out of this bipartite division.

turn allow further range expansion (*cf.* Roebroeks 2001, 442).

Notwithstanding fluctuating hominin numbers (and possibly frequent regional extinctions), if not genes, then ideas and technologies could have been exchanged during migration events. In the Out-of-Africa narrative, these migration pulses are thought to have involved three main routes. The westernmost engages crossings of the Gibraltar Straits (fig. 2.1), but claims for movements across the Straits (*e.g.* Arribas and Palmqvist 1999) have been repeatedly disputed (*e.g.* Straus 2001; Derricourt 2005; Carbonell and Rodríguez 2006; O'Regan *et al.* in press). Even more compellingly rejected is the likelihood of contacts between N. Africa and Italy through the Sicilian Channel (Villa 2001). A third route, which does not involve sea-crossings and it is so far considered as the strongest candidate, involves the Levant, Asia Minor/Near East and the Balkans (Bar-Yosef 1994, 1998; Darlas 1995a; Dennell and Roebroeks 1996; Runnels 1995; Straus 2001; Panagopoulou *et al.* 2006; Carbonell and Rodríguez 2006; van der Made and Mateos 2010). Passing through familiar palaeoenvironments, *i.e.* similar to those of the African open grasslands, hominins could have moved towards inland Europe by following the Palestine corridor into Asia Minor and the Balkans. As noted in section 6.4, there was no marine connection between the Black Sea and the Aegean until the Late Pleistocene: both the Dardanelles and the Bosphorus Strait were land-bridges, as it was also much of the Aegean Sea before about the penultimate glacial period and during (at least) the glacial periods of the Early and most of the Middle Pleistocene. The semi-arid, continental environments of the Anatolian plateaus, marked by the ranges of Taurus and Pontic mountains on its respectively southern and northern margins, may have acted as barriers, but the role of Anatolia as a bridge cannot be ruled out, in view of some new discoveries there (*cf.* Kuhn 2010).

What can be relatively safely stated is that, during the greatest parts of the Early and Middle Pleistocene, the Aegean Sea would *not* have always been a barrier, but instead, its emergent land-masses would have enabled direct biogeographic connections between Anatolia/Southwest Asia and the southernmost part of the Balkan refugia, namely the Greek

Peninsula. In that sense, Greece lies within not only the aforementioned 'eastern route' of African-Eurasian contacts, but also amidst the most probable route(s) for *east-to-west intra-Eurasian movements*. Dmanisi presents a similar case: its location provides support to the importance of the 'eastern route'; its fauna is of predominantly European affinities, and it is in a region with a climate and a physiography comparable to that of Greece (Gabunia *et al.* 2000). Recently, it has been stressed that "the area of SE Europe and SW Asia around the Black Sea [...] is the area where the humid faunas of Europe and Northern Asia intergrade with the faunas that lived in the arid area that extends from N. Africa to Central Asia" (van der Made and Mateos 2010, 196). In fact, the same study indicates that the majority of Pleistocene species dispersing into Western Europe originate in Asia, and that human dispersal into Western and Central Europe may have involved populations living in southern or central Asia. On the other hand, the widely-held view that *Homo* would have moved together with other taxa, for instance as part of broader 'faunal events', has been challenged (O'Regan *et al.* in press). Yet, there is one important conclusion from the research of O'Regan and colleagues (*ibid*): in the Afro-Eurasian Pliocene and Pleistocene, the predominant pattern of dispersal was east-west rather than north-south, in other words, between Europe and Asia, rather than Africa. The same team had pointed out earlier that faunal exchanges between Africa and the Levant were minimal during the Middle Pleistocene (O'Regan *et al.* 2005).

Essentially in the same line, a study of almost the entire hominin fossil dental record of the late Pliocene and Pleistocene suggests that "the evolutionary courses of the Eurasian and the African continents were relatively independent for a long period and that the impact of Asia in the colonization of Europe was stronger than that of Africa" (Martín-Torres *et al.* 2007). This conclusion is echoing earlier calls for "attention to the comparability of data sets [in this case: between Africa and Asia] when evaluating whether or not the absence of hominins [for that matter, in Asia] is more than the outcome of taphonomic circumstance or the history of fieldwork" (Dennell and Roebroeks 2005, 1103): Asia includes vast areas that remain unexplored and it still keeps yielding surprises (*e.g.* Flores, Dmanisi). Thus, before assuming

that a hominin (*e.g. H. ergaster*) migrated from Africa into Asia, researchers need comparable data sets to justifiably infer that it was indeed absent before the date of its first appearance, *i.e.* to assess its ‘last probable absence’. Obviously, the latter is hardly ever safely demonstrable, as the 700,000-years-old site of Pakefield (southern England) exemplifies: until 2005 no convincing artefacts had been found there, despite two centuries of investigations of the Cromer Forest-bed Formation, in which the site is included (Parfitt *et al.* 2005). The latter site is currently the earliest known in Europe north of the Alps, and it is worth mentioning here that, similar to the oldest site in Eurasia (Dmanisi), its environmental context indicates a warm and seasonally dry Mediterranean climate (*ibid.*). Only few of the artefacts from Pakefield were retrieved from fluvial silts and overbank sediments (*ibid.*) and such fine-grained contexts are overall exceptional for early Pleistocene archaeology. When a coarse-grained matrix (*e.g.* of river gravels) is combined with a small assemblage of a few taxa of mostly large species, the comparatively small and fragile remains of hominins are unlikely to be preserved (*cf.* Dennell and Roebroeks 2005, 1100 for the biasing effects of this situation on the Asian records). This applies also to caves, cavities and open

fissures, notwithstanding the enhanced chances of preservation in such settings (*e.g.* Simms 1994) or the fact that these are often the key sources of fossil vertebrate remains (*e.g.* see Athanassiou 2002 for the faunas of Thessaly, chapter 4). The problems surrounding the excavation of Petralona Cave (4.2.1) does not render it a good example to explore such issues, but the finding of a *H. heidelbergensis* cranium allows us to address the relevant question: if we exclude for the moment the Greek artefactual testimony, should the date of the Petralona specimen (*ca.* 200 ka) be considered as the ‘first appearance date’ of that species in Greece? Assessing the ‘last probable absence’ of *H. heidelbergensis* in Greece is not a primary focus, but the research presented here indicates that a negative answer to this question is most likely. Considering the history of palaeontological and archaeological investigations in Greece, the difficulty in assessing ‘last probable absences’ lies only partly in the degree of research intensity: the large gaps in the palaeontological and palaeoanthropological archives suggest that the core of the problem revolves around the effects of geomorphic processes that have resulted in a significantly fragmented geoarchaeological data set.

3 – Lower Palaeolithic records of the circum-Mediterranean area

3.1 INTRODUCTION

In this chapter, a critical overview of the circum-Mediterranean Lower Palaeolithic record is presented. The evidence from each region is discussed in relation to the best-studied sites and with regard to broader patterns that can be extracted. One of the main objectives of my research is to examine the early Palaeolithic record of Greece within the framework of the earliest occupation of Europe; to this end, we first need to consider some of the most important aspects characterizing not only the records of neighboring regions, such as the Italian peninsula or the Balkans, but also those of more remote areas, such as the Iberian peninsula. Besides the meager evidence of the Balkans, the circum-Mediterranean area was chosen because it is the most relevant to Greece in many respects, namely in terms of geomorphology, topography, geology, tectonic history and climate. The main conclusions of this examination will serve as a framework of reference, against which the Greek evidence will be compared in chapter 7. The examination here will allow the reader to make her/his own comparisons between the Greek evidence and the Lower Palaeolithic of the rest of the Mediterranean, and the author to refer to sites, dates and contexts from the Mediterranean Lower Palaeolithic, whenever this is necessary for a better understanding of the Greek record.

Additionally, this section serves another purpose, which could be dubbed the ‘de-mystification’ of the best-studied Lower Palaeolithic records in the Mediterranean. Irrespective of geographical entities but strongly related to research policies and national politics, it is frequently the case that in areas where a couple of uncontested sites exist (and especially, very early sites), the rest of the sites comprising the regional record are unreservedly accepted as sound

evidence, simply because of a ‘shadow of reliability’ cast upon them by the uncontested site(s). Therefore, it is only upon close scrutiny, when the problematic aspects of such well-studied records are brought to light, that a more objective apprehension can be attained for other, less-studied records. In other words, the examination that follows will help us to draw some conclusions also with regard to this question: which of the problems burdening the Greek record are idiosyncratic, and which of them are part of a wider corpus of hindrances, that constrain archaeological studies of the Early and Middle Pleistocene in other regions, too?

The assessment is carried out following two axes of analysis: a site-specific and a regional-specific. In both, the emphasis is given to the three following parameters, assessed in this order of significance:

1. *the depositional environments and geomorphological settings*. The geological context, with which archaeological material is associated, is of crucial importance for the examination and the argumentation that is gradually unfolded in this book. In turn, the geomorphological setting is largely responsible for the nature of the depositional context (primary or secondary). Together they constitute the reference platform for evaluating the next two points.
2. *the dating evidence*. Preferably, the dating of a site should be accomplished by a combination of dating techniques, each one complementing and/or calibrating the others. Nevertheless, ‘absolute’ dates -and ideally, radiometric ones- are preferred over relative dating; for both cases, what needs to be made clear is the association of the dated event or material with the archaeological finds, the nature of the stratigraphic context from which the samples were obtained, as well as any incon-

sistencies between the available dating readings (which should be more than one, if possible).

3. *the artefactual character and the typo-technological ascription of the lithic material.* For example, wherever the material is associated with secondary/derived contexts, the artificial origin of lithic specimens should be demonstrated. Furthermore, as shown below, the long-lasting tendency of ascribing an early age to morphologically 'simple' artefacts should be treated with caution.

With a focus on these factors, I will examine the record of the Italian Peninsula, and then move to the Iberian Peninsula, the evidence from North Africa and that of the Levant, concluding with the record of Turkey and the Balkans.

3.2 THE ITALIAN PENINSULA

The topography, geography and geology of Italy have a lot in common with Greece, as both countries are characterized by two main features: the predominance of coastal and mountainous areas, and a long history of intense tectonism. On the other hand, certain aspects of Italy's tecto-sedimentary evolution are different from those of Greece. In addition, whereas the history of Palaeolithic research in Italy reaches back to the times when Boucher de Perthes, one of the founders of Palaeolithic archaeology, was investigating in the beginning of the 19th century the area near Rome (Mussi 2001, 8), the Greek landscapes were only much later to be surveyed with a clear focus on Palaeolithic remains (Runnels 1995). Hence, research biases and small but significant discrepancies in their geological trajectories might sufficiently explain the marked contrast in the Lower Palaeolithic records of the two countries, but we shall return to this issue later. For a proper evaluation, it is best to consider first the main quantitative and qualitative facets of the Italian record.

Excluding surface collections but including excavated localities with as few as two artefacts, more than forty sites have been claimed to be earlier than or as early as MIS 9, when the Levallois technique begins to emerge³ (Fig. 3.1; Mussi 1995). Overall, the chronological framework of the Italian record has been grounded upon various relative and absolute dating methods, including stratigraphic correlations,



Fig. 3.1 Main Lower Palaeolithic sites of Italy: 1) Visogliano 2) Monte Poggiolo 3) Torre in Pietra, Castel di Guido, La Polledrara 4) Fontana Ranuccio, Colle Marino 5) Ceprano 6) Isernia La Pineta 7) Pirro Nord 8) Venosa Loreto, Notarchirico

palaeomagnetism, biochronological indicators and a wealth of radiometric dates. The latter have been in many instances obtained from the dating of effusive products of volcanoes that were deposited during the considerable volcanic activity of the Pliocene and Pleistocene, which was in turn associated with tectonic movements. Related to the orogenesis of the Apennines since the late Miocene, compressive tectonics on the eastern periphery of the mountain range formed an alteration of deepened basins and uplifted areas, while from late Tortonian up to early-middle Pleistocene times, an extensional regime affected the inner (western) part of the Apenninic range, produ-

3. Mussi (2001, 37) states that "the Levallois technique is not found at any well-dated site prior to stage 9- and possibly even later", explicitly putting the Lower-Middle Palaeolithic boundary upon the appearance of Levallois for organizing her book on the Palaeolithic and Mesolithic of Italy.

cing a series of small basins oriented mostly parallel to the NW-SE orographic trend, such as those of Isernia, Anagni and Venosa (Martini and Sagri 1993; Ghisetti and Vezzani 1999). When at around 1.0 Ma the uplifting of the Apennines was renewed, the landscape became more rugged and the basins were disrupted and drained by rivers: for instance, in the Isernia basin, which was filled by a lake during the Early Pleistocene, neotectonic activity resulted in stream capture and faulting of the Pleistocene deposits (Coltorti *et al.* 1982; Mussi 2001).

Many of those intra- and circum-Apenninic basins have preserved long fauna-yielding sequences: abundant documentation of mammalian localities enabled the construction of detailed biochronological schemes, wherein important faunal events are calibrated by independent chronological controls and compared with the record of small mammals, allowing for biostratigraphic subdivisions, identification of boundaries and correlation between different regions and individual archaeological sites. It is certainly not a coincidence that most mammal ages for both large and small European mammals have been formalized based on Italian type-localities (*e.g.* Villafranchian, Galerian, Aurelian; Raia *et al.* 2006; Sala and Masini 2007; but see also Palombo and Sardella 2007 for the problems of mammalian sequences and their correlations with the geochronological time-scale). The succession of faunal units not only provides an independent means for calibrating ('absolute') dates but it occasionally offers also insights into specific bioevents, which, together with other lines of evidence (*e.g.* palaeobotany, palaeopedology) facilitate the understanding of climatic/environmental changes, thereby allowing for palaeoenvironmental reconstructions.

In the narrow Italian peninsula, a great component of geomorphological and sedimentary processes is related to the presence of *ca.* 9,000 km of coasts and has therefore been considerably influenced by sea-level fluctuations; this affords the Italian Pleistocene archaeology the privilege of correlations with isotopic stages recognized in the marine records, in contrast to other parts of mainland Europe (Mussi 1995). Nevertheless, the 'marine control' of the sedimentation has its own side-effects: the reduction of the sea level forced rivers to incise, rejuvenating and altering

their drainage systems, so that erosional planes were developed inland (*e.g.* see Amato *et al.* 2003 for an example of estimated rock volumes that have been eroded since middle Pleistocene times). As a consequence, there is an apparent bias in the archaeological record towards warm climatic phases, when stability generally prevailed over erosion. Accordingly, it is essentially in caves and fluvio-lacustrine basins serving as sedimentary traps, where the geo-archaeological archive is most adequately preserved.

Monte Poggiolo, which is one of the oldest known sites, is located now in the valley of the Po River (currently the largest lowland area of Italy), but when humans were present there, the site is assumed to have been closer to the coast, as the Po valley would have been a gulf of the sea (Mussi 1995). Archaeological remains were found in the fluvatile sandy gravels of a deltaic deposit which is argued to be correlative to littoral sands ('Imola Sands') that crop out in some distance from the site; the latter deposits comprise a supra-regional stratigraphic marker, they yielded a reversed magnetic polarity that is thought to indicate a pre-Brunhes age, and have been ESR-dated to the interval between the Jaramillo and the Brunhes (Amorosi *et al.* 1998; Milliken 1999). Thus, the combined dates indicate an age between *ca.* 0.8 to 1.0 Ma, but doubts have been expressed on the validity of the palaeomagnetic measurements, and, importantly, on the fluvatile nature of the sediments and hence the very same correlation with the Imola Sands as well (Roebroeks 1994, 303; Villa 2001, 123). The assemblage of Monte Poggiolo comprises mainly core-choppers and flakes knapped from flint pebbles, which are overall thought to indicate a 'simple and opportunistic lithic technology' (Peretto 2006). Whereas no fauna has been preserved, foraminifera, ostracods and molluscs indicate a marine coastal environment, close to freshwater and brackish marshes (Milliken 1999).

Isernia La Pineta, located in the Upper Volturno Basin in the center of Italy, has been for long regarded as the 'flagship' site for the Italian Lower Palaeolithic, mainly because of its primary fluvio-lacustrine context, which yielded an impressive core-and-flake industry associated with abundant faunal remains that provide possible evidence for butchering; yet, the identification of distinctive 'living floors' is not

unproblematic (Villa 1996; Mussi 2001; Coltorti *et al.* 2005). Four archaeological layers that are believed to be close in time have been found sandwiched between the earliest fluvial deposits and the latest episodes of lacustrine sedimentation (Mussi 2001). The dating of these layers is considered to be controversial (Villa 2001). A K/Ar date of *ca.* 730 ka was obtained from volcanic particles, which according to the excavators are fresh and not reworked (Coltorti *et al.* 1982; but see also Mussi 1995, 30). More recent and more detailed Ar/Ar data are thought to better refine the age of the site at around 600 ka (Coltorti *et al.* 2005), an estimate that is closer to the chronological indications deriving from the macro- and micro-fauna (notably, due to the presence of *Arvicola terrestris cantiana*; Roebroeks and van Kolfschoten 1994).

In another basin, that of Venosa, the archaeological finds from the site of Notarchirico were recovered from lacustrine and fluvio-lacustrine deposits rich in pyroclastics and they include a human femur and nine bifaces, among assemblages dominated by chopping tools on pebbles (Sala 1991; Milliken 1999). The combined results from an array of absolute dating techniques (U-series, TL, Ar-Ar), bio-chronological indicators (*e.g.* *Arvicola cantiana*) and correlations with episodes of volcanism, altogether suggest an early Middle Pleistocene age for Notarchirico, perhaps close to 650-600 ka (Sala 1991; Villa 2001). The rest of the main Lower Palaeolithic sites date to the middle and late Middle Pleistocene, with ages generally clustering between *ca.* 500 and 300 ka: Loreto in Venosa basin (Mussi 2001); Fontana Rannuccio and Colle Marino in the Anagni basin (Biddittu *et al.* 1979; Segre and Ascenzi 1984; Villa 2001) and Ceprano from the eponymous basin (Ascenzi *et al.* 1996; Muttoni *et al.* 2009) (both of the latter basins being located in the valley of the Sacco and Liri rivers); Torre in Pietra, La Polledrara and Castel di Guido in the valleys of 'Via Aurelia' (Anzidei and Arnoldus-Huyzenveld 1992; Mussi 1995; Constantini *et al.* 2001). The site of Visogliano is also noteworthy: it is located in a karstic depression on the side of a small doline in the Trieste Karst, it has yielded human remains from the filling of a rockshelter and a breccia outside the rockshelter, and it is radiometrically dated (U-series, ESR) to between *ca.* 500-300 ka, with the mammalian assemblage point-

ing to the middle part of the Middle Pleistocene (Abbazzi *et al.* 2000; Falgueres *et al.* 2008).

Besides Visogliano, all other sites are open-air sites associated with fluvial, lacustrine or fluvio-lacustrine depositional settings, within or at the margins of Apenninic basins and/or along former coastlines, as with the case of Monte Poggiolo and the sites of Via Aurelia; moreover, all are located *below the altitude of ca. 500 m*. Considering the indications provided by the study of tectonic activity and associated geomorphological processes, it can be said that none of the sites were situated in mountainous areas at the time of their occupation; instead, the reconstructed topographic settings suggest "flat or gently undulating parts of the territory" (Mussi 2001, 42). According to the emerging pattern of distribution, all sites relate to water bodies (lakes, rivers, coasts) and are located in lowland settings. Nonetheless, it is difficult to assess whether this reflects a preservation bias or hominin site location preferences, or (most probably) both, because there are negative and positive arguments for both cases (*cf.* Mussi 2001). On one hand, the inner mountainous areas with a rugged relief would have been prone to erosion, especially during glacial periods, frequently disturbed due to tectonism and its associated effects, such as drainage diversions and stream incision; in contrast, depressed terrains trapped sediments and protected them from erosion, whilst sites close to river mouths would have been quickly buried by alluvial deposits. On the other hand, wherever environmental palaeo-reconstructions are available, they seem to suggest that those basinal features (*e.g.* lakes) provided habitats rich in resources, hence probably favorable to hominins. Alternatively, the Aurelian sites indicate that not all water-bodies may have been equally attractive: the densely forested, 'closed' environment of the Riano lake appears to have been avoided, in contrast to the nearby lacustrine areas of La Polledrara and Castel di Guido, where an open landscape seems to have been preferred (Anzidei and Arnoldus-Huyzenveld 1992; Mussi 2001). Furthermore, it is important to note here that hominins continued to 'settle' within those tectonically-controlled basins and lakes in the folds of the Apennines also during the Middle Palaeolithic, in environments not very different from those of the earlier periods (Mussi 2001, 59). In contrast, the Lower Palaeolithic altitudinal threshold of *ca.* 500

m. is exceeded after about 300 ka, when Middle Palaeolithic sites are found equally on hilly, mountainous landscapes. In addition, the overall scarce evidence for the use of caves in the Italian Lower Palaeolithic may be reflecting a preference for open-air environments -perhaps also ‘open’ ones as opposed to ‘closed’ in terms of vegetation cover- but it could equally be the result of behavioral constraints or preservation biases, among other reasons. The fact remains that the Middle Palaeolithic of Italy is indeed predominated by cave-sites, although their overwhelming majority (a minimum of seventy) date to the last glacial (which could be also an artefact of preservation; Mussi 1999). All things considered, the current state of knowledge does not allow for a more detailed comparison of Lower versus Middle Palaeolithic sites with regard to site preservation and distribution, and hominin preferences (Mussi 2001).

As regards the lithic industries, there seems to be no considerable preferences on raw materials, since poor quality chert and limestone were being habitually used. The rather crude knapping techniques, the apparent predominance of core-and-flake (often designated as ‘Mode 1’) assemblages, and the relatively opportunistic flaking considered to be evident in some of these early sites, could be related to the properties of the raw materials, or to specific activities and functional needs. Handaxes are present, albeit rare, as for example in Notarchirico and Fontana Ranuccio, and they are the only component for ascribing the Acheulean label to some assemblages. So-called ‘proto-handaxes’ are reported from Monte Poggiolo and Visogliano, whereas bifaces are found interstratified with core-and-flake industries at Notarchirico (Mussi 2001). A chronological sequencing with ‘core-chopper industries’ preceding those with handaxes has been convincingly proved to be no longer tenable (Villa 2001 *contra* Peretto 2006), whilst the earliest-dated biface assemblages do not show any traits pointing to the African Acheulean (Villa 2001). Finally, there is also a chronological trend, as handaxes become less frequent and (nearly) disappear from later sites, *e.g.* from Middle Palaeolithic sites of MIS 7 such as those buried by loess in north-eastern Italy⁴ (Mussi 2001).

Recently, three flint cores and six flakes were recovered from fossiliferous karst fissures at the site of Pir-

ro Nord, and were dated to *ca.* 1.7-1.3 Ma on the basis of the associated mammal biostratigraphy (Arzarello *et al.* 2007, 2009). However, the published photographs and drawings of the specimens (Arzarello *et al.* 2009, fig. 1 and 3) cast some doubts on their artificiality⁵, whilst the biochronology-based suggested age needs also further calibration, as some researchers argue that the mammal assemblage does not preclude an upper age limit of *ca.* 0.87 Ma (Mut-toni *et al.* 2009, 267). Thus, excluding Pirro Nord, if we accept the correlation of the artefact-yielding deposits at Monte Poggiolo with the Imola Sands, the latter would be the only relatively well-dated site of the (late) Early Pleistocene in Italy. Villa (2001, 126) stresses that the existing four sites for the time span between 0.8 and 0.5 Ma (*i.e.* Monte Poggiolo, Isernia, Notarchirico and Ceprano, although the latter is recently re-dated to somewhat later, at 0.45 Ma) yield an average of one site for every 100 ka. This fact, together with the observation that the density of sites only increases in the second half of the Middle Pleistocene (after *ca.* 450 ka), indicates “multiple, sporadic, and discontinuous episodes of settlement into the peninsula until higher densities of population allowed the formation of a more stable prehistoric record and more distinct tool-making patterns” (Villa 2001, 126). Nonetheless, there appear to be no significant changes in the density of sites and the resources that were used, when the pre-300 ka record is compared to the last part of the Middle Pleistocene at *ca.* 300-130 ka and the beginning of the Middle Palaeolithic period (Mussi 1999, 2001).

Whilst some would interpret the Italian record as pointing to multiple episodes of migration (*e.g.* Villa 2001), others would agree to a twofold scenario of colonization at around 1 Ma and then later at around

4. Interestingly, Mussi (2001, 78) notes that those -more than a hundred- sites buried by loess in the margins of the Po plain “are labeled as Acheulean because of the few handaxes sometimes found but are clearly Middle Palaeolithic in all respects”.

5. The researchers argue against any transport of the lithics and the possibility of dealing with geofacts. In my view, the conglomeratic matrix of the fissure filling in which these lithics were found requires a better argumentation on their artificiality; even if fluvial transport can be excluded (as the researchers suggest) the filling of the fissure is bound to have included some sort of mass transport, whilst the clast size of the matrix indicates a high-energy transport agent.

650 ka BP (Palombo and Mussi 2006). Although both views are ready to associate human dispersal with faunal migrations, it is in the second hypothesis that human colonization is directly linked with animal migrations and faunal renewals, when human subsistence and survival would have been assisted by an increase of middle-sized herbivores and a concomitant decrease of carnivores (Palombo and Mussi 2006). Faunal composition and diversity regulates the animal biomass available for hominins, and it is in turn depended on the type of climatic-environmental belts. The richness of the Italian record may well be attributed to the mosaic character of the environment, as suggested by Mussi (1995, 2001): the varied topography and climate of Italy is accentuated by the marked altitudinal gradient and the presence of the Apennines, providing a variety of heterogeneous and rich resources over short distances. If early humans were indeed ‘generalists’ in their diet and used a non-specialized tool-kit, then the mosaic landscapes of Italy would have been best suitable for them, and not only in periods that these environments would have acted as refugia.

3.3 THE IBERIAN PENINSULA

The Iberian Peninsula (*ca.* 580,000 km²) can be divided into the following main geographical regions (Raposo and Santonja 1995): 1) the northern part of Portugal, Galicia, and the Cantabrian Range and littoral zone 2) the northern Meseta, a flat area with a mean elevation of 800 m asl, and the Iberian Chain, in the center of the peninsula 3) the western Portuguese littoral and the lower Tagus basin, in the west 4) the southern Meseta, which is separated from the northern by the mountains of the Central System, and includes the Tagus and Guadiana basins, as well as the Extremadura plateau 5) the Ebro basin and the zone of the Pyrenees in the northeast 7) the basins of Algarve, Segura and Andalusia in the south.

Although the Mediterranean coasts of Spain have been adequately investigated, Lower Palaeolithic sites have not been found there; similarly, sites on the Cantabrian and western Portuguese coasts have yielded either non-stratified artefacts and/or assemblages that have been assigned an age according to their typological classification, hence with a problematic dating (Santonja and Villa 1990; see for exam-

ple Rios *et al.* 2008 for a recently found ‘Lower Palaeolithic site’ in the Biscay province). Overall, the earliest sites in entire western Iberia are on the current evidence not older than MIS 8-9; they have yielded mainly surface finds and their chronological attribution is deemed only tentative, as it is essentially based on the typological characteristics of the artefacts (Oosterbeek *et al.* 2010). In short, the best-documented Lower Palaeolithic evidence of Iberia comes from sites that are located in the continental interior (Fig. 3.2).

The oldest known sites of Iberia have been discovered in the intramontane basinal complex of Guadix-Baza (GB), a depression controlled by a set of normal faults, situated in the Betic Cordillera of southern Spain (province of Granada). Sedimentation in the GB basin was almost continuous from Late Miocene up to the Late Pleistocene, forming depositional cycles that begin with fluvial sediments of fans and fan deltas and end with lacustrine deposits of ephemeral lakes; overall, the sedimentary strata are flat-lying and display only localized deformation (Martínez-Navarro *et al.* 1997; Gibert *et al.* 1998b; Oms *et al.* 2000). Significant tectonic events are generally not recorded in the basin, and the most prominent tectonic feature is the Baza fault, which separates the Guadix sub-basin in the west from that of Baza in the east (Pérez-Peña *et al.* 2009). The palaeotopography entails a division of the continental sediments into a marginal and a distal environment: the former is mainly represented by the fluvial sediments of the conglomeratic Guadix Formation, whereas the distal domain consists largely of lacustrine deposits of the Baza Formation (Agustí *et al.* 1999). The sedimentary sequence of the latter domain is locally over 100 m-thick and includes exceptional exposures of horizontal deposits, in which numerous palaeontological sites have been found: the micro- and macro-faunal assemblages of the Baza basin have been for long under study, producing an extensive literature on micromammal systematics, biostratigraphy and faunal replacements, often directly touching upon early human dispersals (Gibert *et al.* 2006 and references therein).

Located in the northeastern sector of the Baza basin and close to the town of Orce, Fuente Nueva 3 (FN3) and Barranco León (BL) are the most important sites

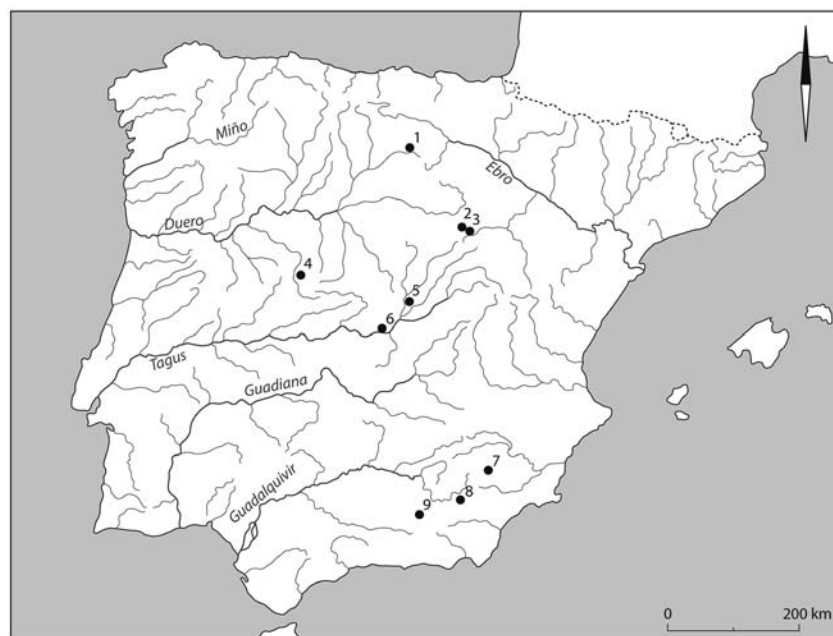


Fig. 3.2 Main Lower Palaeolithic sites of Iberia: 1) Atapuerca sites: Trinchera Dolina, Sima del Elefante, Sima de los Huesos 2) Ambrona 3) Torralba 4) La Maya 5) Aridos 6) Pinedo 7) Estrecho del Quípar 8) Orce sites: Fuente Nueva 3, Barranco León 9) Solana del Zamborino

with faunal and lithic material. Both are situated along tributary creeks of the Orce river and they belong to the upper, ‘silty calcareous member’ of the formation, which was deposited in a lacustrine environment and consists of limestone, carbonate silts and mudstones (Oms *et al.* 2000). The artefact-bearing deposit at BL contains fine-grained sands of the distal part of a small alluvial system, whilst the sediments of FN3 belong to a marginal lacustrine setting (Gibert *et al.* 1998b). Until 2002, 295 artefacts had been recovered from the excavations at BL, most of them made on flint, but also on quartz, quartzite and limestone pebbles; notably, according to Santonja and Villa (2006, 432) the assemblage includes discoid cores, flakes used as cores, well-configured scrapers and proportions of faceted butts approaching 8%. The lithic artefacts of FN3 are similarly manufactured mainly on flint and less on limestone cobbles, they exclusively comprise of cores and flakes, and they include pieces with a blade-like tendency and products indicative of centripetal flaking from discoid cores (Martínez -Navarro *et al.* 1997; Santonja and Villa 2006). Due to their core-and-flake character and the absence of handaxes, the industries from both sites have been described as ‘Oldowan / evolved Oldowan’ and they are thought to signify the existence of a pre-Acheulean technological stage in Europe, which is purportedly related with a distinct dispersal event from Africa into Europe by ho-

minins carrying a ‘Mode 1’ toolkit⁶ (Martínez -Navarro *et al.* 1997; Gibert *et al.* 1998b; Carbonell *et al.* 1999; Carbonell and Rodríguez 2006). The vertebrate fauna from both sites, and most notably the morphology and degree of evolution of some arvicolids, like *Allophaiomys bourgondiae* (*cf. lavocasti*) and *A. chalinei*, indicates an age in the Early Pleistocene, which is refined to *ca.* 1.4 Ma on the basis of the regional biozonation along with other biostratigraphical data and biochronological comparisons and correlations with other early sites, such as Le Vallonet or Dmanisi (Martínez -Navarro *et al.* 1997; Oms *et al.* 2000; Agustí *et al.* 2010). Extensive magnetostratigraphic studies were carried out in various localities within the basin but also directly in the sediments containing the lithic industries; a reverse magnetization that was recorded throughout the stratigraphic sections is correlated with the Matuyama Chron, ascribing the archaeological levels between the Jaramillo and Olduvai Subchrons, *i.e.* in accor-

6. A recent technological study of the artefacts from the two sites by Barsky *et al.* (2010) recognizes a grouping of raw material types with specific technological characteristics: flint was mostly used for the production of flakes, whilst limestone was preferred for percussion implements and worked cobbles; nevertheless, this study essentially retains the tagging of Mode 1 (as opposed to Mode 2), as well as its supposed relation with hominin phylogeny and discrete colonization episodes.

dance with the age-estimate suggested by the biostratigraphy⁷ (Oms *et al.* 2000; see also Scott *et al.* 2007).

The locality of Venta Micena, found in deposits of the Baza formation, yielded a faunal assemblage of more than 15,000 fossils including some highly controversial ones: some humeral diaphyses and a cranial fragment have been reported to belong to either *Homo* (Gibert *et al.* 1998a, with a history of the reports and references therein; Gibert *et al.* 2008) or *Equus* (Palmqvist 1997; Palmqvist *et al.* 2005). The faunal material resembles French Villafrancian assemblages dated to 1.6 to 0.9 Ma, and record a faunal break with the arrival of Asian and African species (ibid; Palmqvist 1997, 83). Venta Micena records a reversed magnetization (Oms *et al.* 2000) and its fauna contains taxa that appear also in Dmanisi (Georgia) and Apollonia-1 (Greece) (Martínez-Navarro *et al.* 1997, 616). Similar problems apply to the cave site of Cueva Victoria, located also in southeastern Spain. A phalanx that was found there was first assigned to *Homo* (e.g. Palmqvist *et al.* 1996), but recently it has been re-assessed and is now considered to belong to *Theropithecus oswaldi* (Palmqvist *et al.* 2005), although the controversy continues (e.g. see Gibert *et al.* 2008 *versus* Martínez-Navarro *et al.* 2008).

Solana del Zamborino, situated at the Guadix Basin, is an open-air site with a sequence of fluvial and lacustrine deposits that yielded a rich Acheulean assemblage. Although the site was for long ascribed an age at *ca.* 200 ka on the basis of the Acheulean typology, recent magnetostratigraphic analysis by Scott and Gibert (2009) showed that the artefact-bearing layers are positioned immediately above the Matuyama-Brunhes polarity reversal, hence they are now

considered to date to *ca.* 770 ka. The same researchers carried out palaeomagnetic examinations at another site, Estrecho del Quípar, which is a rockshelter situated on the northeastern margin of the Baza Basin. The lithic artifacts here include pieces with prepared platforms, centripetal and recurrent flaking and disc-cores, but also a handaxe made on limestone (Scott and Gibert 2009). Here, the entire sequence is reversely magnetized and the researchers assigned the artefact-bearing strata to the late Matuyama subchron, at *ca.* 900 ka (ibid, 84). Therefore, Solana del Zamborino and Estrecho del Quípar are now considered to provide the earliest-known evidence for the presence of handaxes in Europe (ibid).

Next to the Orce sites, the Iberian contribution to the discussion on the earliest occupation of Europe consists of a number of archaeological and palaeontological sites discovered in the karst system of Sierra de Atapuerca, a small mountain range between the basins of the Duero and Ebro rivers, at the northeastern border of the Iberian Meseta (e.g. Bermúdez de Castro *et al.* 2004). The sites are grouped into two main cave systems, the Cueva del Silo and the Cueva Mayor; the site of Gran Dolina (or, 'Trinchera Dolina', hereafter referred to as TD) and those of the Galería complex could belong to a separate system, while Sima de los Huesos and Sima del Elefante are the most famous sites from Cueva Mayor. Exposed due to the opening of a railway trench, the filling of the Gran Dolina karst revealed an 18-meters section of 11 lithostratigraphic units, numbered from bottom to the top, with sediments of interior (TD1 and TD2) and exterior facies (TD3-4 to TD11), with the latter, allochthonous deposits of TD3-4 to TD11 representing clast and mud gravity flows from the surroundings of TD (Parés and Pérez-Gonzales 1999).

Human fossils from a minimum of ten individuals together with faunal remains and lithic artefacts of 'Mode 1' technology have been recovered so far from unit TD6 (Carbonell *et al.* 1995; Bermúdez de Castro *et al.* 2008). The human remains of Atapuerca have been considered to represent a new species, named *Homo antecessor*, which is thought to be distinct from *Homo erectus* and may have been ancestral to both *Homo heidelbergensis* and the Neanderthals (Bermúdez de Castro *et al.* 1997). Palaeomagnetic measurements document a reversed pa-

7. Note however that "lateral facies changes are significant throughout the GB basin, hampering physical correlation between strata from these two locations [i.e. BL and FN3]" (Oms *et al.* 2000, 10667); moreover, palaeomagnetic determinations demonstrated the occurrence of re-magnetizations in some localities of the basin, which overall call for attention when using magnetostratigraphic correlations. See for example the discussion and disagreements between Martínez-Navarro *et al.* 1997 and Gibert *et al.* 1998a, and between Gibert *et al.* 2006 and Agustí *et al.* 2007, the latter also with regard to issues concerning the biostratigraphic data.

laeomagnetic signal which, coupled with ESR and U-series dating, suggested an age in the range of 857–780 ka for TD6 (Falgueres *et al.* 1999). The microfauna has been attributed to the end of the Biharian biozone based on the evolutionary stage of the Arvicolids (Cuenca-Bescós *et al.* 1999; López-Antoñanzas and Cuenca-Bescós 2002), but this chronological placement has been contested by van Kolfschoten (1998), who argues that the fauna does not contain species restricted to the Early Pleistocene but, rather, it includes taxa which in Europe occur during the early Middle Pleistocene; in extent, this could suggest that the reversed-polarized sediments record an intra-Brunhes magnetic event. Arribas and Palmqvist (1999, 575) also stress that, whereas typical Middle Pleistocene taxa originating in Asia are included in the TD6 level, early Galerian species are lacking as it would be expected due to the proposed age; on the contrary, mammals which first appear during the Middle Galerian are represented, which suggest that “from a biostratigraphical point of view, this assemblage should therefore be included within the Middle Galerian, in the base of the Middle Pleistocene”⁸.

In the Sima de los Huesos, the enigmatic accumulation of human remains from 28 individuals is still puzzling archaeologists, and various explanations have been proposed to explain this taphonomic mystery, which is accentuated also by the presence of one, single artefact: a handaxe made on quartz, a material that is uncommon in the Atapuerca sites (Arsuaga *et al.* 1997). The hominins represented by the Sima de los Huesos sample display Neanderthal-derived features together with more incipient traits, and are thought to be ancestral to Neanderthals –most probably *H. heidelbergensis*. Such a possibility makes the recent dating of the site at *ca.* 600 ka even more fascinating, as this is the time when the Neanderthal lineage begins, according to DNA studies (Bischoff *et al.* 2007).

Last but not least, the cavity infilling at Sima del Elefante recently yielded a human mandible that is provisionally assigned to *Homo antecessor* (hence in

line with the remains from Gran Dolina), with an associated lithic assemblage consisting of 32 artefacts, mainly small and simple flakes; based on combined results from palaeomagnetism, cosmogenic nuclides and biostratigraphy, the hominin-bearing level has been dated to 1.2–1.1 Ma (Parés *et al.* 2006; Carbone *et al.* 2008). Consequently, Sima del Elefante provides so far the oldest *direct* evidence for a human presence in Europe in the Early Pleistocene.

The next important sites are those of Torralba and Ambrona, located at an altitude of *ca.* 1110 m in the valley of the Rio Masegar, between the basins of the Duero, Tagus and Ebro rivers, in the northern Meseta (Butzer 1965; Freeman 1975). Although at both sites the depositional environment of the archaeological levels refers to fluvial/fluvio-lacustrine deposits, it is important to note their geomorphological setting: Ambrona is situated in a polje and Torralba lies on the edge of a doline (Santonja and Villa 2006). The earliest lithic assemblages from the two sites are generally described as late Acheulean (Santonja and Villa 1990), with that of Torralba containing discoid cores and highly standardized flake tools (Freeman 1975; Santonja and Villa 2006). Combined ESR/U-series dating indicates a minimum age of 350 ka for Ambrona, whilst Torralba is younger (*ibid.*; Falgueres *et al.* 2006). Noteworthy, Ambrona had for some time a central position in the debate about early human hunting- *versus* scavenging-based meat procurement (see Villa *et al.* 2005 for a recent evaluation).

As becomes apparent from this short overview, there appears to be a small group of sites dating to the Early Pleistocene (Fuente Nueva, Barranco Leon and Sima del Elefante, all dated at *ca.* 1.3–1.2 Ma), whilst another group would involve a few late Early-early Middle Pleistocene sites (Atapuerca’s TD6 at *ca.* 0.8 ka and Sima de los Huesos at *ca.* 0.6 ka); the rest of the Iberian Lower Palaeolithic record is -by and large- comprised of sites which have been loosely and/or tentatively dated to the late Middle Pleistocene (Santonja and Villa 1990; Raposo and Santonja 1995; Santonja and Villa 2006; Santonja and Pérez-González 2010). The vast majority of those sites (1) occur in the continental interior and mostly on the Meseta (2) are described as ‘Acheulean’ (3) are associated with fluvial settings, and (4) usually lack preserved fauna. Intensive surveys car-

8. For concerns raised with regard to the (biochronological) dating of Atapuerca see also Roebroeks and van Kolfschoten 1995, 305, and Dennell and Roebroeks 1996, 536.

ried out on the Iberian river basins have demonstrated an overall lack of stratified occurrences in the middle-high and high river terraces; instead, almost all known sites -be that with or without stratified finds- appear in the levels of the *middle terraces* (e.g. at +30 m, as is mostly the case with the sites in the Tajo, Duero and Mino river basins), often associated with high-energy deposits (e.g. Pinedo, La Maya, Torralba), whilst others relate to low energy, primary contexts (e.g. Aridos I and specific levels of Ambrona) (Santonja and Villa 2006; Santonja and Pérez-González 2010). This strong association of sites with fluvial settings is explained as the result of alluvial geomorphic processes that “generate deposits and conserve remains” (Santonja and Pérez-González 2010). On the other hand, the fact that sites are usually found related to second and third order confluences of fluvial systems and/or on the vestibular areas of secondary valleys, is thought to reflect hominin preferences (Raposo and Santonja 1995, 9). In this line, the scantiness of the record from, for instance, the Mediterranean and Cantabrian coasts or Galicia, is explained by the fact that Middle and Early Pleistocene river deposits either have not been preserved there (Santonja and Pérez-González 2010), or the irregular discharge regime of rivers and the frequent floods did not favor the preservation of archaeological material (Santonja and Villa 2006). In contrast to the latter case, syn-sedimentary subsidence could account for the high density of finds in fine-grained floodplain sediments in the terraces of the Manzanares River (ibid). On the other hand, the basin of the river Ebro includes well-developed Middle Pleistocene deposits, and yet the area is virtually devoid of early Palaeolithic remains (Raposo and Santonja 1995, 15).

In sum, although the earliest-dated and best-preserved sites are associated with karstic or lacustrine settings, the Iberian Lower Palaeolithic record is predominated by fluvial depositional environments. The available chronological framework is principally based on relative chronologies derived from the study of fluvial morphostratigraphic sequences, which in some cases afford calibration by other dating techniques, most notably palaeomagnetism and biochronology. Terrace formation is thought to have been controlled more by tectonic processes and the nature of the geological substratum and less by cli-

matic fluctuations (Raposo and Santonja 1995). Similarly, differences in surface (e.g. Duero) or stratigraphic (e.g. Tagus) positions of artefacts are seen as reflecting temporal differences in aggradation and incision cycles between the hydrographic systems (Santonja and Villa 2006).

3.4 NORTH AFRICA

Although North Africa is rich in palaeontological and early Palaeolithic sites, its chronological framework for the Early and Middle Pleistocene is still poorly established, or at least quite contentious. One of the reasons is that material suitable for absolute dating (e.g. volcanic rocks) is generally lacking, and most dating methods, as for example Uranium-series, are appropriate mainly for the final part of the Lower Palaeolithic sequences; furthermore, biostratigraphic correlations are often controversial, especially when they involve long distances between localities, whereas palaeomagnetic results are usually open to contrasting interpretations (e.g. Clark 1992; Raynal *et al.* 1995). Another reason would be the orientation of the earliest investigations towards a cultural-historical sequencing of the sites based on typological categorizations of the lithic assemblages, with a concomitant overlooking of chronostratigraphic data, whilst most of the earliest-found localities have not been revisited since the 1950s (Sahnouni 1998, 3). Hence, one is left with only a handful of sites untouched by uncertainties, insofar one excludes the following (ibid): surface finds; reworked materials from secondary and/or high-energy matrix or polycyclic colluviums, and pseudo-artefacts (Raynal and Texier 1989, 1744); selectively collected artefacts (e.g. only the ‘pebble tools’).

Thus, serious doubts have been expressed on the dating of the palaeontological locality of Ain Boucherit and the early Palaeolithic sites of Ain Hanech and El-Kherba, all three contained in the newly defined Ain Hanech Formation (Sahnouni *et al.* in press). When it was discovered in 1947, Ain Hanech was the first site in N. Africa to yield a Plio-Pleistocene fauna associated with Lower Palaeolithic artefacts. After new archaeological investigations (Sahnouni 1998; Sahnouni and de Heinzelin 1998), the site is currently thought to record the oldest archaeological occurrence in N. Africa, with a coherent ‘Mode I’ assem-

blage similar to industries found in East African Pliocene-Pleistocene sites, and with an assigned age of *ca.* 1.8 Ma (Sahnouni *et al.* 2002; but see below).

East of the Atlas Mountains, Ain Hanech and El-Kherba are located at about 1200 m asl on the Ain Boucherit valley, within the Beni Fouda basin, which is one of the several basins of the Eastern Algerian high plateau, with ages ranging from the Late Miocene to the Late Pleistocene (Sahnouni 1998). The localities are in a sedimentary outcrop cut by a deep ravine of the intermittent Ain Boucherit stream, and are surrounded by a series of highlands. Stratigraphically, El-Kherba and Ain Hanech are laterally equivalent and were formed in the fluvio-lacustrine depositional environment of the Beni Fuda Pliocene-Pleistocene basin (Sahnouni and de Heinzelin 1998). Similar stone artefacts were retrieved from three strata (A, B and C) that are present at both localities. Overall, the deposits of these layers indicate an alluvial floodplain cut by a meandering river channel. The researchers suppose that, during the deposition of level A, the river had created an oxbow lake and hominin activities took place on the floodplain proper, whilst during level B human activity occurred on the riverbank (*ibid*; Sahnouni *et al.* 2002). They conclude that the artefact-bearing deposits are indicative of repeated visits of hominins at a shallow river embankment -a location preferred for the availability of good quality raw materials in the nearby river bed, and the passage of game. The raw materials are flint and limestone, whilst flaking patterns and typologies of artefacts from both sites are seen as resembling those from upper Bed I and lower Bed II of Olduvai; notably, Acheulean artefacts occur only in the uppermost part of the sequence and are considerably younger. The ‘Oldowan’ artefacts occur in deposits with a normal palaeomagnetic polarity and overlie reverse-polarized sediments. The normal polarity is correlated with the Olduvai subchron (1.95-1.78 Ma) on the basis of biostratigraphic indications deriving from the fauna that was found in Ain Hanech and Ain Boucherit Formations (Sahnouni *et al.* 2002). Geraads *et al.* (2004) criticized the correlation with the Olduvai subchron, stressing that the Jaramillo normal subchron is not discussed as a possibility by Sahnouni and colleagues; furthermore, they disagree on the biostratigraphic arguments that have been presented in support to the proposed age of ~1.8 Ma

(but see Sahnouni *et al.* 2004 for a reply). As Sahnouni *et al.* (in press) admit, many of the faunal species have a wide chronological distribution and the suggested age-estimate is essentially based on three or four taxa; furthermore, some long-distance correlations (e.g. for the suid *Kolpochoerus* from zones at Koobi Fora; Sahnouni *et al.* 2002, 930) might be seen as problematic.

Besides the aforementioned Algerian sites, most of the North African best-studied sites, namely Thomas-I Quarry, Grotte des Rhinocéros (formerly Thomas-III quarry) and Sidi-Abderrahman, are part of a series of localities clustered in the vicinity of Casablanca, on the Atlantic coast of Morocco. The region preserves an exceptional succession of littoral formations, exposed in large quarries (Raynal *et al.* 2001). This series of marine deposits interbedded with terrestrial sediments, was used by Biberson (1961) to construct a stratigraphical and sedimentological sequence for the marine stages of the Pleistocene in the Maghreb, showing also the successive stages of the Lower Palaeolithic industries through time. His classic work on the basic classification of the littoral-marine record is still being used as a yardstick, if not re-examined by other researchers (Texier *et al.* 1985; 1994; Lefevre and Raynal 2002) and incorporated in a new lithostratigraphical, biochronological and archaeological framework (Raynal *et al.* 1995). In their revision of Biberson’s work, these scholars (Raynal and Texier 1989; Raynal *et al.* 1995) have questioned the antiquity of the earliest-claimed assemblages: in fact, they have shown that, so far, there is no ‘Pebble Culture’ recorded *in situ* at Casablanca and no important fossiliferous site is known yet for the early and middle Early Pleistocene of the region. Accordingly, although the Atlantic littoral of Morocco has been considered as providing one of the most complete Pleistocene successions of the world (Howell 1962 quoted in Stearns 1978, 1630), an early or middle Early Pleistocene age for the archaeological horizons in the Casablanca sequence is now doubted (Raynal and Texier 1989; Raynal *et al.* 1995; 2001; 2002). The picture changes in the Middle Pleistocene, when traces of human occupation increase substantially. Well-developed deposits allow for a detailed lithostratigraphic analysis, where seven marine units are identified, which are stepped between 9 and

35 m above sea level and covered by continental fossiliferous deposits (Texier *et al.* 1994).

A series of formations is identified, and these correspond to regressive sequences, which overall indicate a succession of marine foreshore/backshore and aeolian (dune) depositional environments (Texier *et al.* 1994). In Thomas Quarry-I (TQ-I), level L of Formation 1 of the Oulad-Hamida Group furnished with its late Early Pleistocene deposits the best evidence of the Early-Middle Pleistocene transition, yielding the oldest lithic assemblage of the Casablanca sequence (Raynal *et al.* 2001). The industry consists of Acheulean artefacts made of quartzite and flint. Level L corresponds to the beginning of the Amirian continental phase, when sandstones and limestones were formed over a long period of time (Raynal and Texier 1989); this allowed the formation of karstic caves, subsequently occupied by humans and animals (Clark 1992). The overlying level M2 contains marine sands and records the ultimate 'Maarifian' high sea-level marine phase (close to MIS 21; Texier *et al.* 1985, 184; Stearns 1978; but see also Texier *et al.* 1994, 1248). Thus, as included in Formation 1, which is considered to be older than MIS 21 (between 1.4-0.8 Ma; Raynal *et al.* 2001: Table 1), Level L has been assigned an age between 1.0 and 0.7 Ma. The minimum age of 0.7 Ma is in accordance with Stearns' hypothesis (1978) about layers in a similar stratigraphic position at Sidi-Abderrahmane Quarry (Raynal and Texier 1989). On the grounds of palaeomagnetic and biostratigraphic data, a date close to 1.0 Ma seems reasonable to Raynal *et al.* (2001); more recently, Geraads *et al.* (2004) opt for an age between 1.5-1.0 Ma, which they consider to be in accordance with OSL dating results, too. The presence of the suid *Kolpochoerus*, absent from the rest of the levels in Thomas/Oulad Hamida Quarries and from Ternifine⁹, is thought to be in accordance with the proposed age around 1.0 Ma (Raynal *et al.* 2002).

Further up in the stratigraphy, unit M³ of marine fine sands represents a high sea level shoreline, which is part of a major morphogenetic phase in the Middle

Anfatian (which corresponds, roughly, to the Holsteinian of the European chronostratigraphy; see table in Texier *et al.* 1985). Thomas Quarry I- Hominid Cave ('Grotte à Hominidés') belongs to this shoreline; there, in 1969 a hominid mandible was discovered and attributed to *Homo erectus*, whereas more recently, three new teeth of *Homo* were found. According to Raynal and Texier (1989, 1743), the filling of this 'marine cave' postdates the beginning of the Middle Anfatian. Raynal *et al.* (2001; 2002) have suggested an age of 0.4-0.6 Ma as a *minimum*, on the basis of litho- and biostratigraphic data; moreover, they report that the macrofauna is similar in composition to that of the 'GDR Cave' (see below), and shares some taxa with the locality of Ternifine. Nevertheless, the provenance of the mandible has been (Jaeger 1975, 411) and still is considered to be problematic (Raynal *et al.* 2001), whereas Jaeger (*ibid.*) had also raised doubts on the derivation of the macrofauna.

The Grotte des Rhinocéros (GDR) is part of the Oulad Hamida 1 Quarry, where in the 1980s remains of *Homo erectus* associated with a 'Middle Acheulean' assemblage and fauna were discovered. The stratigraphy of the cave resembles that of Thomas I Quarry and most of the units have the same chronology. The excavated strata are part of a marine cave on a Middle Pleistocene shoreline, most probably occupied during an arid period with low sea-level (Raynal *et al.* 1993). The results of ESR-dating gave an age of about 0.4 Ma, which is considered to be in accordance with the overall evidence of the fauna (Rhodes *et al.* 1994). Lately, Raynal *et al.* (2002: 69) refer to unpublished lithostratigraphical data that could increase the minimum age of GDR at 0.6 Ma.

Biberson's 'Acheulean sequence', especially the last phases, is best represented in the Sidi Abderrahman localities: Schneider Quarry, Grande Exploitation, Cap Chatelier, Grotte des Littorines, Bears Cave and Sidi Abderrahman Extension (Raynal *et al.* 2001). These quarries expose a complex series of marine and aeolian beds (Stearns 1978), the oldest of which represent a late regressive stage of the 'Maarifian' transgression. In 'Bears Cave', dated at the boundary of MIS 12 and 11, a recent phase of the Middle Acheulean is represented, whereas Cap Chatelier exemplifies an upper stage of the Acheulean and it is

9. This is another Algerian site with hominin remains, dated at 1.0-0.6 or at 0.7 Ma.

older than MIS 9, according to OSL dates (Raynal *et al.* 2002).

The long sequence at Casablanca covers the last six million years. Although Miocene-Pliocene environments are well-represented by rich palaeontological sites, like Lissasfa (considered as 5.5 Ma old) and Ahl-Al-Oughlam (dated at *ca.* 2.5 Ma), the first traces of human presence come from deposits which are substantially later: the late Early Pleistocene layers in unit L of Thomas Quarry I have yielded the oldest lithic assemblages of ‘Lower Acheulean’ artefacts, whereas the first human remains come from the same quarry and were found in Middle Pleistocene deposits, associated with ‘Middle Acheulean’ lithic tools. The terraces which provide this exceptional record stretch from 180 m asl down to the present sea-level, and are associated with intertidal depositional units, dune formations, alteration facies (karsts, palaeosols), and reworked deposits (Raynal *et al.* 2001). Overall, the littoral deposits record transgressions and regressions which presumably reflect global and local fluctuations in sea-level. Previous studies considered that the Moroccan strandline sequence could use a broad chronological framework based on the assumption of uniform rates of emergence and in correspondence with a general history of sea-level changes (Stearns 1975). Alternatively, Texier *et al.* (1994) call for attention to the fact that the exact role of tectonic and glacio-eustatic processes, which probably controlled the formation of those littoral deposits, are not well-understood. Consequently, the identified events (transgressions, regressions, dune formations, etc) cannot be directly and securely correlated with marine isotope stages.

In the case of the Ahl-Al-Oughlam Quarry, littoral dunes and cliffs within a mosaic environment can be reconstructed for the period around *ca.* 2.5 Ma, based on the fauna. This karstic fissure-filling is the richest fossiliferous locality of this time period in North Africa and it records a humid palaeoclimate and open woodland (Raynal *et al.* 1990). Pebble tools, discovered by Biberson in a high energy marine layer, are now considered to be geofacts by Raynal *et al.* (2001, 68), who stress that, despite the diversity of the fauna, human remains were not found –a fact that is regarded as evidence of hominin absence (Geraads *et al.* 2004). The fauna of Ahl-Al-Oughlam

includes *Macaca* and *Theropithecus* species, which have also been found in Early Pleistocene localities of southeastern Spain. Other Maghreb Plio-Pleistocene localities have yielded some Holarctic mammalian taxa, but as it is in the case of African species that reached Europe, their presence cannot *prove* crossings of the Gibraltar Straits, especially when one considers that the Levantine route offers an undisputable alternative (*cf.* Straus 2001; but see Arribas and Palmqvist 1999 for a different view). Nonetheless, the antiquity of the quoted ages for Ain Hanech has revived the claims for crossings of the Gibraltar Straits by early hominins (*e.g.* Gibert *et al.* 2008).

Yet, if we are to treat with caution the palaeomagnetic results and the controversy around the biostratigraphic data from the Algerian sites, then the most reliable dates (*i.e.* including radiometric assays) come from the Atlantic Moroccan sites. The latter suggest that the earliest human presence in North Africa did not occur before the late Early Pleistocene (Thomas Quarry I), whilst the most reliable dates would put this earliest presence well within the Middle Pleistocene (Grotte des Rhinocéros). Moreover, in contrast to the ‘Oldowan’ assemblages from the Algerian sites, the evidence from Morocco suggests that the initial occupation of North Africa is associated with human groups carrying an Acheulean toolkit.

3.5 THE LEVANT

The Levant occupies a central place in the debate about Pliocene-Pleistocene migration routes between Africa and Eurasia, as it provides the only secure biogeographical bridge amongst the two continents: either across the Suez region, or via the southernmost part of the Arabian peninsula and then across the Bab-el-Mandeb Strait, movements of animal and human groups would have continued along the Red Sea into the Levantine corridor, which would in turn facilitate their spreading both eastwards and westwards. Yielding age estimates that are widely accepted, and containing cultural and faunal material indicative of both African and Eurasian affinities, key Levantine sites like ‘Ubeidiya and Gesher Benot Ya’aqov (see below) constitute strong proof of the role of this corridor; particularly those two sites have

been interpreted as evidence of two distinct waves of African migrations, with separate and culturally different entities (Goren-Inbar *et al.* 2000; Bar-Yosef and Belfer-Cohen 2001).

At the site of Yiron, a few flakes found in a gravel bed that is seen as underlying a basalt layer are claimed to be older than 2.4 Ma based on the age of the basalt (Ronen 2006). Similarly, cores and flakes occurring in the Erq-el-Ahmar Formation in sediments of normal geomagnetic polarity are considered to date to *ca.* 1.77–1.95 Ma (Olduvai Subchron), given the age of a covering basalt (Ron and Levi 2001). However, the evidence from both Yiron and Erq-el-Ahmar have not yet gained wide acceptance from the palaeoanthropological community. Other noteworthy evidence from the Levant include the handaxes and the exceptionally small implements from the Evron Quarry, loosely dated to between 1.0 and 0.78 Ma but, on the basis of the fauna, possibly being slightly younger than ‘Ubeidiya (Ronen 2003; Ron *et al.* 2003); and the site of Ruhama, also tentatively dated to *ca.* 0.9–0.87 Ma (Ronen 2006; Laukhin *et al.* 2007).

On the current evidence, the best-dated, earliest known site in the Levant is ‘Ubeidiya. The site of ‘Ubeidiya is situated in the central Jordan valley (a segment of the Dead Sea Rift), on the flanks of the western escarpment of the Jordan Rift. There, the 150 m-thick sedimentary sequence of the ‘Ubeidiya Formation (Fm) crops out, exposing an alteration of fluvial and lacustrine members (Goren-Inbar 1995). Post-depositional tectonic movements resulted in the folding and faulting of the sediments, which were tilted in dips of up to 90°, forming two anticlines (*ibid.*). The archaeological material is embedded in two main depositional environments, a lacustrine with low-energy silts and clays, and a fluvial with high-energy conglomerates and sands (Belmaker *et al.* 2002). Palaeoenvironmental reconstruction indicates a delta of an ephemeral stream debouching into a freshwater lake, whose shores fluctuated during alternating episodes of regression and transgression; when the lake receded, early humans are envisaged to have camped on its shores, at the edges of an alluvial fan and on mud flats or temporarily dried swamps (Bar-Yosef 1994, 231). Avian and mammalian species of the faunal assemblage

point to diverse biogeographical areas of origin and suggest a wide range of ecological niches (Goren-Inbar 1995). Importantly, the fauna contains a mixture of African (*e.g.* *Megantereon whitei*) and Eurasian taxa (Martínez -Navarro *et al.* 2009); moreover, a hominin incisor has also been identified (Belmaker *et al.* 2002). The lithic assemblages have been originally considered to fall within the categories of ‘Developed Oldowan’ and ‘Early Acheulean’, as they include chopping tools, discoids, polyhedrons and spheroids that resemble those from Olduvai Bed II, but also numerous handaxes; however, the recognition of two distinct cultural entities was soon to be reconsidered, and the Ubeidiya assemblages are now seen as belonging to a single continuous tradition, as part of the ‘Acheulean Industrial Complex’ (Goren-Inbar 1995, 106). On the basis of the biostratigraphy, palaeomagnetic determinations (a reversed polarity) and the position of the Ubeidiya Fm between two dated basalts, the site was initially dated to between 1.4–1.0 Ma; recently, a new biochronological analysis of the fauna refined the age for the fossil- and artefact-bearing strata to 1.5–1.2 Ma (Martínez -Navarro *et al.* 2009).

The other important site of the Levant, Gesher Benot Ya’aqov (GBY), is located in the Dead Sea Rift, in a narrow valley south of the former shoreline of the Hula palaeo-lake, on the banks of the Jordan River. In the Hula Basin, freshwater lakes and marshes were formed as the basin began to subside, with lacustrine and paludine sediments becoming interstratified with basalt flows. As in the case of ‘Ubeidiya, tectonic movements resulted in the faulting and folding of the lacustrine deposits and the formation of the GBY Embayment, which is now the only location where the GBY Fm crops out (Goren-Inbar *et al.* 1992). The exposed sequence documents a change in the depositional setting of the embayment, when the quiet domain of a marshy lake gave way to an environment of pronounced fluvial activity (*ibid.*). Thus, fluvial conglomerates are found at the bottom and top of the sequence, while the intermediate layers are wholly lacustrine or lake-margin in character (Goren-Inbar *et al.* 2000). More than thirteen archaeological horizons have been identified within the sequence, representing repeated occupations on the shores of the palaeo-lake, whereas dense concentrations of burned artefacts are thought to document recurrent

use of fire by hominins (Alpers-Afil 2008). The artefact assemblages are characterized by a strong bifacial component (with a high ratio of cleavers) and are assigned to the Acheulean Industrial Complex. It has been argued that the African traits recognized in the lithic industry represent a diffusion of ideas and populations from Africa, instead of a locally-evolved phenomenon (Saragusti and Goren-Inbar 2001). The site is also rich in palaeobotanical remains: among seeds, fruit, and pollen, noteworthy are the exceptionally preserved waterlogged fragments of wood (Goren-Inbar *et al.* 2000). The fauna includes Asian and African taxa and is described as Galerian (Bar-Yosef 1994). Both normal and reversed magnetic polarity zones are recorded at the site and the polarity boundary is situated below the primary archaeological horizons. On the grounds of the biostratigraphic indications and the lithic evidence, the polarity boundary is interpreted as the Matuyama-Brunhes Chron boundary, hence assigning the site to *ca.* 0.8–0.7 Ma (Goren-Inbar *et al.* 2000).

As for the rest of the Levantine Lower Palaeolithic sites, it is rather difficult to discuss their spatio-temporal distribution or technological variability, mainly because the existing chronological and classificatory schemes are still grounded on the sequencing of ‘cultural entities’ according to typological – and to a lesser extent technological – characteristics of the lithic assemblages: the use of terms such as Early, Middle and Late Acheulean, or Tayacian, Tabunian, Achel-Yabrudian and Amudian, may be nowadays less favored, yet it still complicates the assessment of old collections (*cf.* Goren-Inbar 1995). Nevertheless, the Levantine record essentially appears to be as fragmentary as most of the other circum-Mediterranean records: apart from the aforementioned Early Pleistocene evidence and that of the late Middle Pleistocene (*e.g.* from Tabun E, Yabrud I and Qesem caves), there seem to be substantial gaps as far as the early and middle Middle Pleistocene are concerned (*cf.* Bar-Yosef 1994; 1998; Goren-Inbar 1995).

An emphasis on the investigation of cave sites has resulted in an apparently biased over-representation of this site-type, whilst fluvio-lacustrine open-air sites like ‘Ubeidiya and GBY may be demonstrating the importance of locales that were in direct association with water bodies. Be it an artefact of preserva-

tion, or a reflection of hominin preferences, the fact is that occupation of caves in the Levant emerges as a relatively recent phenomenon (Goldberg 1995, 53). Research biases aside, the uneven nature of the record calls for an examination of topographical, geological and geomorphological features, of which the distribution, degree of preservation and heterogeneity may have also been filtering the broader picture with respect to both chronological frameworks and depositional settings.

The topography of the Levant is marked by coastal and inland mountain ranges, the Dead Sea Rift (the rift of the Orontes-Jordan valleys), and plateaus which are dissected by streams that flow to the east into the Syro-Arabian desert (Bar-Yosef 1994). Upland areas include the Judea and Samaria mountains, the Galilee, the Golan, and the Central Negev Highlands, whereas lowland regions are found in the coastal plain and the Western Negev. Today, the wider zone of the Mediterranean Levant is covered by Eu-Mediterranean vegetation of woodlands and open parklands on and along the coastal areas.

There is a wide variation in past landscape-types, including lacustrine, fluvial, coastal, and karstic environments. Of particular interest is the area of the Rift Valley, where many lakes were formed throughout the Quaternary. Lacustrine environments associated with archaeological material are primarily limited to this part of the Levant, particularly in the Jordan valley and its northern segment, the Hulla valley, where the sites of ‘Ubeidiya and GBY have been found, respectively. In the central Jordan valley, the Erq-el-Ahmar Formation is a good example of a Plio-Pleistocene fluvial landscape associated with a Lower Palaeolithic site; other examples would include the Acheulean artefacts recovered from the fluvial deposits of the Nahariyim Fm, which post-dates ‘Ubeidiya, and the assemblages found in the gravels of the Orontes river at Latamne in Syria (Goldberg 1995). However, fluvial settings are overall patchy in their spatial and temporal distribution (*ibid.*).

The coastal zones are relatively flat, whilst their width has been controlled by sea level fluctuations. Coastal landscapes are marked by the so-called *kurkar* sediments, which are cemented calcareous sandstone ridges, and the *hamra*, red loam deposits; both

are products of transgressive-regressive sedimentation cycles and are often associated with Palaeolithic artefacts, mainly resting on or embedded in hamras (Laukhin *et al.* 2007). Acheulean artefacts related to hamras have been found in the Evron Quarry, as well as at Ruhama and Revadim (*ibid.*). Researchers agree that hamras represent a type of paleosol, but their origin and environment of formation, likewise those of the kurkar sandstones, are still under discussion; it is generally assumed, though, that stabilization due to vegetation cover during wetter periods caused the development of hamra reddened soil horizons, which were subsequently eroded locally and redeposited (Goldberg 1995, 50). Finally, besides surface and *in situ* sites in hamras, the coastal zone preserves residues of human presence also within caves.

The chronological framework of the Levant is thus based mainly on lacustrine and fluvial sequences, marine shorelines and coastal formations, aided by correlations based on magnetostratigraphic and biochronological evidence, as well as with palaeoclimatic chronologies from the deep-sea cores or the European terrestrial sequences (Bar-Yosef 1994). The division of Quaternary cycles on the grounds of marine raised beaches and coastal sequences, and inland sequences of river terraces, cannot always provide direct correlations between, for instance, the Dead Sea Rift sites and the coastal plain, due to the biasing effects of geological processes (Goren-Inbar 1995).

Indeed, it is essentially the geomorphic processes that are responsible for the fragmentation of the geo-archaeological archive. As Goldberg (1995) shows, the temporal distribution of Quaternary landforms and deposits is marked by considerable gaps in all geomorphological settings. For example, most of the extant cave deposits represent less than 10% of the Quaternary time-scale (*ibid.*, 53). Similarly, lakes were in existence for less than half of the Quaternary, and many of them, as for example those of the Negev area, appear only in the late Pleistocene. In the same line, the geological signature of fluvial and alluvial activity is also much discontinuous, especially with regard to the Middle Pleistocene, for which alluvial occurrences are extremely patchy (Goldberg 1995, 45). Likewise, coastal landforms lack stratigraphic continuity; although the kurkar/hamra couples appear

to have a long-lasting existence, Goldberg notes (1995, 53) that usually they cannot be temporally differentiated and in reality they are distributed in a much more punctuated fashion –an observation which is in accordance with a recent study of these features and their correlation with Palaeolithic sites (Laukhin *et al.* 2007).

3.6 BALKANS AND TURKEY

In the Balkans, the evidence for an Early and Middle Pleistocene human presence is still sparse and inconclusive (*e.g.* Galanidou 2004). In marked contrast to the long history of Palaeolithic investigations in most of the rest of Europe, research in the Balkan region lagged considerably behind and it is only in the last couple of decades that projects targeting the Palaeolithic are being launched, although in a still slow pace. Isolated finds and assemblages of lithic artefacts that were collected in the beginning of the 20th century and up till the 1970's suffer from a poor documentation, which is commonly restricted to a typological description of the specimens, a few drawings and the assigning of the finds to a 'cultural period' (*e.g.* 'Abbevillian', 'Clactonian', etc); particularly the latter, a classification according to morphological criteria, was commonly the major concern, outweighing the recording of stratigraphic data (*e.g.* Doboş 2008). Moreover, there is a general lack of publications by Balkan scholars in languages such as English or French, which would make their reports more widely accessible. For all the above reasons, and due to the paucity of published accounts, an overview of the 'Balkan Lower Palaeolithic' is bound to be short and sketchy.

Itself a notable exception, a recent review of the Lower Palaeolithic of Romania illustrates dramatically the above-mentioned problems (Doboş 2008). Firstly, there is the issue of old -and now obsolete- terminology that has not been completely abandoned, as with the case of the term 'Osteodontokeratic industries' (alleged tools on bones, supposedly preceding the use of stone-tool technology), or the 'Tres Ancien Paléolithique' ('TAP', supposedly preceding the Acheulean) and the 'Premousterian'. Secondly, all of the artefacts that have been found *in situ* either have not been documented adequately (or at all), or their artefactual character would now be considered

uncertain, let alone that the finds are usually limited to 2-3 specimens (*ibid*). Thirdly, excluding the ‘*in situ* finds’, most of the locations reported as Lower Palaeolithic involve disturbed contexts, mainly related to river terraces; ‘choppers’ and ‘chopping tools’ in these cases are essentially stray finds, with many of them being of a dubious anthropogenic origin, whilst the remaining pieces “should not be used as chrono-cultural markers” (Doboş 2008, 230). The conclusion of this examination was that the existence of the Lower Palaeolithic in Romania is doubtful.

Similarly, only a few Palaeolithic sites have been recorded so far in the (Former Yugoslav) Republic of Macedonia but none of them has been assigned a secure age estimate (Kuzman 1993). The picture is much better in Albania, partly as a result of a recent survey project, which investigated intensively the hinterland of the Fier Province in central Albania (Runnels *et al.* 2009). There, only thirteen artefacts (including three bifaces) were assigned a Lower Palaeolithic age; these are surface finds discovered at four sites, all of which are situated on or between anticlinal ridges that run down to a valley (*ibid*). At one of the sites (Rusinja), an eroded paleosol that is exposed on the summit of an anticlinal ridge is estimated to be older than *ca.* 100 ka; the deposition of the artefacts on the surface is thought to pre-date the formation of the paleosol, which in that case provides a *minimum ante quem* for the age of the artefacts (*ibid*, 157). Yet, apart from this relative dating, the attribution of the artefacts to the Lower Palaeolithic is obviously based on the typological characteristics of the specimens and the occurrence of certain morphotypes (*e.g.* bifaces).

Recently, excavations in the cave of Kozarnika in north-east Bulgaria unearthed from the lowest layers core-and-flake lithic assemblages as well as a human tooth, all attributed to the Lower Palaeolithic (Gaudelli *et al.* 2005). The artefacts are made on local flint and their artefactual character seems to be beyond doubt. On the basis of the macro- and micro-faunal remains (which include *inter alia* the rodent *Mimomys savini*), as well as preliminary palaeomagnetic results, the researchers suggested an age between 1.4-0.8 Ma for the lowermost layers (13 to 11c) and 0.6-0.4 Ma for the upper layers (11b and a) of the ‘Lower Palaeolithic levels’ (*ibid*). In the latest

publication, the age of the site is pushed back to 1.6-1.4 Ma; in the table showing identified faunal taxa, a question mark is placed next to the *Homo* specimen, which is not discussed in the text (Sirakov *et al.* 2010). Thus, further research that would refine the age of the artefact-bearing layers and clarify the identification of the hominin tooth is much awaited.

Moving into Turkey, the data-set becomes significantly richer than that of the Balkans, but it is still conspicuously fragmented if we consider the time-span covered by the Early and Middle Pleistocene and the size of the country (see Fig. 2.1 for locations of main sites). Although a substantial number of surface finds of handaxes and other potential Lower Palaeolithic artefacts have been collected (*e.g.* Kuhn 2002; Taskiran 2008), there are currently only four/five sites with Lower Palaeolithic material from a documented and secure geological context. The gaps in the Turkish / Anatolian record can be largely attributed to the degree of research intensity and coverage, but for some areas, such as the Central Anatolian Plateau, geological factors mainly account for the scarcity of sites: for large parts of the plateau, Miocene strata are exposed on the surface and Pleistocene deposits are absent, whilst in other parts the Pleistocene is buried by thick sequences of younger sediments; alternatively, the few identified sites are associated with margins of Pleistocene lakes or with outcrops of limestone or volcanic rocks (Kuhn 2002).

The latter association is seen at the site of Dursunlu, situated on the Lycaonian plateau in south-central Anatolia, where purported artefacts were recovered from the lacustrine sediments of lignite beds that have been exploited in a lignite mine (Güleç *et al.* 2009). Palaeomagnetic measurements did not document the Brunhes-Matuyama boundary, but recorded two normal-polarity episodes that have been interpreted as the Jaramillo and Olduvai subchrons, respectively; the fauna- and lithics-bearing layers are said to be situated well within an upper interval of reversed polarity and above the normal-polarized sediments, hence they are thought to predate the Brunhes-Matuyama boundary and post-date the Jaramillo (*i.e.* between 0.99 and 0.78 Ma). The age-range of microfauna (including *Mimomys savini*) and macrofauna fossils are seen as supporting this chron-

ological estimation (*ibid*). The dating of the site may prove to be correct, but there seem to be problems concerning both the provenance and the artefactual character of the archaeological material. The lithic pieces were collected “within and around large blocks of consolidated sediments that had been abandoned on the surface after quarrying operations ceased...Many of the artefacts were excavated from the intact sediment blocks [...] although the blocks themselves were not observed in their original positions, because the primary deposits are now inaccessible due to the flooding of the quarry” (Güleç *et al.* 2009, 15-16). Moreover, the upper lignite unit, with which the archaeological finds are correlated, did not yield any artefacts when it was excavated. Apart from five pieces on flint, the artefacts are made on milky white quartz, and the researchers stress the difficulty in discriminating artefacts from geofacts. From a total of 135 potential artefacts, only 28 had a high score as probable artefacts (*ibid*: Table 1). In short, there are a number of issues that cast doubts on the artefactual character of the assemblage including the following: few artefacts preserve platforms and, those that do, have plain or crushed platforms; 36% of the total is fragments or ‘chips’ without neither proximal nor distal ends; “pieces with retouch or secondary modification are few and largely undiagnostic”; only three (“polyhedral”) cores are reported (Güleç *et al.* 2009, 18). Moreover, although it is argued that “there is no natural agency that could have brought large pieces of vein quartz to this location” (*ibid*, 16), it is then stated that “occasional small, unmodified quartz clasts found within intact blocks of lignite are not rolled” (*ibid*, 17).

Much more solid evidence of human presence is to be found in the site of Kaletepe Deresi 3 (KD3), which was discovered in the course of investigations on Neolithic obsidian workshops, in a volcanic region of Central Anatolia (Slimak *et al.* 2008). The site is close to a large obsidian source and its archaeological horizons are embedded within a 7 m-thick series of alluvial and colluvial layers of volcanic origin that contains also tephras. The earliest archaeological levels yielded Acheulean assemblages consisting of handaxes that were shaped exclusively in obsidian, a few cleavers, but also chopper/chopping tools and numerous polyhedrons; the raw materials are all local volcanic types: obsidian, andesite, basalt

and rhyolite. Noteworthy is a flake pattern that occurs here, which is executed in obsidian and resembles Levallois technology (Kuhn 2010). Faunal material is hardly preserved and the age of the Acheulean levels remains uncertain; only the rhyolitic bedrock is dated to >1.0 Ma, providing a maximum age for the finds (Slimak *et al.* 2008).

Problems surround the dating of another excavated site, the cave of Yarımburgaz in eastern Thrace. The cave is situated close to Istanbul, at the northern shores of Küçükçekmece lagoon, which is an embayment on the northern coast of the Sea of Marmara. It consists of several halls in different levels, of which the lower and the upper chamber, both with entrances towards the river Sazlıdere, have been excavated (Kuhn *et al.* 1996). In front of the cave, what is today a marshy floodplain of the Sazlıdere was a valley with a quartzitic alluvium floor, which may have provided the raw material for stone tools (Arsebük and Özbaşaran 1999). Geomorphological studies have shown that the valley has been heavily eroded during glacial cycles. Thus, the excavators suppose that both chambers would have extended farther than their present entrances: the lower one could have had an additional length of 300 m. beyond its present mouth, hence well into the valley (*ibid*). The lithic assemblage attributed to the Lower Palaeolithic was unearthed from the deposits of the lower chamber, which was also rich in faunal remains. Retouched flake tools dominate the lithic industry, which includes also a small component of core-tools with little morphological standardization and many tested pebbles, whereas the most abundant formal cores are centripetally-worked or discoid specimens (Kuhn *et al.* 1996). The observed wide variety of blank production and core reduction is probably related to the properties and clast shape of the different raw materials that were in use: flint, quartz and quartzite occur in this order of abundance and are followed by jasper and unidentified metamorphic rocks (*ibid*). Flakes and tool blanks tend to be thick and blocky and usually have either cortical or plain platforms; moreover, the degree of elongation is restricted, bifacial and Levallois technologies are absent, whilst ‘heavy-duty’ tools are not uncommon (*e.g.* choppers and chopping tools, denticulates and side-scrapers with scalar, stepped/undercut and abrupt retouch). These features are stressed here because, as mentioned later,

the quartz assemblages from the Greek sites of Rodia (Thessaly) and Doumbia (Macedonia) are considered to display similarities with that from Yarimbürgaz.

A deposit with sand and fine gravel that is exposed only in the upper chamber is thought to correspond to a last interglacial beach (Tyrrhenian) and helps to date the archaeology-yielding strata of the lower chamber as older than the last interglacial (Arsebük and Özbaşaran 1999). However, this deposit does not occur neither in the lower chamber nor in the passage connecting the two chambers; furthermore, the Pleistocene sediments of the upper chamber have been reworked by more recent (post-Pleistocene) inhabitants of the cave and it is acknowledged that any correlation of the sequences from the two chambers is problematic (ibid, 63). ESR dates from *Ursus deningeri* teeth “range from Oxygen Isotope Stage 6 back through Stage 9” (Kuhn *et al.* 1996, 34). Even though this dating technique is not ideally applied on cave-bear teeth, both the ESR results and palaeontological indications point to the latter half of the Middle Pleistocene (Kuhn 2002).

The difficulties in acquiring solid dating results are not restricted to the aforementioned sites, but include also the best-studied Palaeolithic locality in Turkey, the cave of Karain. This is again a multi-chambered cave situated on the south-facing flanks of the Taurus range and close to the Mediterranean coast, in a calcareous area with numerous cavities, rockshelters and springs (Otte *et al.* 1995). Karain E is the main chamber with Lower and Middle Palaeolithic deposits, in a sequence composed of interfingering colluvial, travertines, clayey-silty layers and calcitic concretions associated with paleosols (ibid). The lowermost, archaeological unit A yielded an assemblage that was termed ‘Clactonian’ and consists of a few artefacts made on radiolarites; cores exhibit a rough centripetal or polyhedral shape, flakes are short and thick and the toolkit is dominated by denticulates and notched pieces (Otte *et al.* 1998). The layers of this unit were estimated to date around 400-370 ka (see below). The next units, B to E, contained assemblages that were termed (proto-) ‘Charentian’, as they exhibit a more elaborate debitage rich in side-scrapers but still including denticulate forms; these assemblages were considered similar to the ‘Achelo-Yabrudian’ of the Levant and were esti-

mated to date around 350-300 ka (ibid). Notably, a few fragmented human remains were also found in unit E, but they have not yet been taxonomically determined (Otte *et al.* 1998). With the beginning of the next group of units (F through I), a major change is seen in the sequence of knapping techniques: the Levallois method appears, together with materials from extra-local sources; average ages from ESR and TL datings place the appearance of Levallois and the beginning of these ‘Typical Mousterian’ assemblages’ at *ca.* 250-200 ka (Otte *et al.* 1998, 419). The age-estimates suggested for the Lower Palaeolithic assemblages of unit A and B to E were “estimated on the basis of correlation with oxygen isotope stages” (ibid: Table 1). These correlations were based on the following argumentation: ESR dates on teeth gave ages averaging 120 and 110 ka for layer I.2 (unit I), which was therefore correlated to the Last Interglacial; then, “these readings may indicate that the underlying consolidated travertine layers represent preceding interglacial phases and thus their age may be estimated by correlation with the isotope curve established by Shackleton and Opdyke” (Otte *et al.* 1999, 77). In my view, whereas the ESR/TL average ages of 250-200 ka for the earliest Middle Palaeolithic levels may be seen as secure enough, the proposed estimations for the underlying Lower Palaeolithic levels should be dealt with caution.

Although tentative, the above-mentioned chronological estimation for the earliest Lower Palaeolithic assemblage of Karain is not unreasonable and one might say that it finds some support from another age estimate, this time concerning a travertine that contained a fragmented hominin calvaria attributed to *Homo erectus* (Kappelman *et al.* 2007). The specimen was found in the Büyük Menderes valley in western Turkey, and it was recovered from a block of travertine mined from a quarry. Travertine sediments in this area have been TL-dated between *ca.* 510-330 ka, whilst the most likely date for the travertine that yielded the fossil ranges from around 510 to 490 ka (Kappelman *et al.* 2007 and references therein). The latter estimate falls near the interglacial period that is represented by MIS 13 and this is also the isotopic stage with which the lowest layers at Karain are correlated. Although the age estimates in the two cases broadly match, the problem is that (1) in both sites direct dating evidence is lacking, and (2) in the

case of Karain, a direct correlation of terrestrial sediments (travertine) with marine isotopic stages is in itself problematic.

Apart from the excavated sites overviewed above, a notable number of surface finds from Turkey has been attributed to the Lower Palaeolithic period. A prominent example, much relevant to the picture of the Greek record, regards the artefacts discovered during survey projects on the Asian side of the Bosphorus, and in the area of eastern Thrace and the Sea of Marmara (Runnels and Özdoğan 2001). Bifaces (handaxes), core-choppers and bifacial tools were discovered at a few sites, of which the most important are Eskice Sirti on the European side and Göksu on the Asian side of Bosphorus. The latter site was first documented in 1964 and a more recent revisit confirmed the initial account by Jelinek that the artefacts derive from paleosol exposures; specifically, the findspots at Göksu are located in erosional gullies that cut through mature paleosols formed on the Pleistocene terraces above the Göksu river (Runnels and Özdoğan 2001, 73). The researchers assume that the artefacts are residues from eroded sites that were subsequently incorporated in the soils, in the course of pedogenesis (*ibid*). The implements are made on chert and quartzite and their typo-technological characteristics allow comparisons with the assemblage from the nearby cave of Yarimburgaz. Most importantly, the core-and-flake component of the industry resembles that from the site of Rodia in Thessaly, Greece (see below 6.4). Similar forms and technological traits are noted in the material from Eskice Sirti and it is assumed that both sites could be chronologically comparable with Yarimburgaz and Rodia in Thessaly (at *ca.* 350 ka).

3.7 CONCLUSIONS AND DISCUSSION

The preceding examination of some of the best-studied Lower Palaeolithic Mediterranean sites and the regional records in which they are encompassed, allows us to draw a number of conclusions with regard to the parameters that were mentioned in the introduction as being the focus in this review.

As a general rule, all of those regional records are dominated by open-air sites that are associated with fluvial, lacustrine and fluvio-lacustrine depositional

environments. The latter are commonly related to basinal geomorphological settings, usually of tectonic origin. Most of the sites are located at relatively low elevations, far below 1000 m above sea level, and usually below *ca.* 500 m, as the Italian record vividly exemplifies. All of the exceptions to this altitudinal pattern regard sites that are situated on upland plateaus, and all of them are in altitudes ranging between 1000-1200 m: Torralba and Ambrona on the Iberian Meseta, Ain Hanech and El-Kherba on the eastern Algerian high Plateau, and Dursunlu on the Central Anatolian Plateau. In examining the geography of the European occupation in the Lower and Middle Palaeolithic, also with regard to settlement ecology and landscape use, Hopkinson (2007) arrives at the same conclusion: before around 200 ka, hominin groups seem to have avoided upland regions, and his assertion considers archaeological sites also in northern, central and eastern Europe. Hence, rather than restricted to the Mediterranean, this altitudinal boundary appears to reflect a wider reality in the Lower Palaeolithic of Europe. I would agree with Hopkinson that the explanation of this picture is strongly linked to the ecological dynamics of mosaic landscapes in upland regions: the distributions of plants and animals and the configuration of patches available in these environments were obviously eco-environmental barriers that early hominins could not overcome, probably because of the nature of their social organizations, conceptual abilities and behavioral capacities; thus, Lower Palaeolithic hominins appear to have been confined to lowland habitats where resources were distributed closely in space and time. The same author argues that the Lower Palaeolithic occupation of the Italian Apennines is the exception that proves the rule, because those localities were associated with fine-grained mosaic landscapes, perhaps benefited by the positive effects of volcanism; moreover, he claims that the Apenninic record shows that erosional processes have not biased this picture, which in turn proves that the pattern is real. However, there is not any evidence of human presence in the Italian mountainous landscapes before *ca.* 300 ka (*cf.* Mussi 2001)¹⁰; therefore, instead of the Italian

10. That is, if we consider that 500 m. of altitude is a generally accepted geomorphological boundary for distinguishing between upland and lowland regions in the Mediterranean; it could be

sites, I would consider the aforementioned *sites on the plateaus* as the only significant ‘exceptions to the rule’. The breaking of this altitudinal limitation with the onset of the Middle Palaeolithic may have been real (Hopkinson 2007), but, in my opinion, the Italian record is probably exemplifying exactly the biasing effects of erosional geomorphic agents active in upland landscapes (*contra* Hopkinson 2007). The few Lower Palaeolithic sites of the Iberian, Maghreb and Anatolian upland plateaus can be seen as supporting this argument, because they are situated on flat or gently undulating terrains.

Wherever equally researched areas with comparable geomorphological and depositional settings can be contrasted, it seems that open woodlands close to water bodies would have been preferred locations. Whilst the Iberian record stresses the significance of subsidiary fluvial systems, confluences of rivers and entrances of valleys; the Italian evidence points to the importance of mosaic landscapes. The relevance of those indications for the Greek record is discussed further in chapter 7. Here, it is important to realize that the distribution of sites essentially matches the spatial patterns of fluvial and lacustrine drainage systems. This highlights the importance of drainage catchments in dictating natural routes for inter- and intra-regional human and animal movements: rivers that dissect bedrock and cut through mountain ranges facilitate dispersal events. Lakes, swamps, marshes, riverine and riparian zones are all considered as ecologically highly productive environments; these are commonly hosted within larger topographical depressions, which usually serve as biogeographical corridors. Alternatively, the strong association of sites with fluvio-lacustrine depositional regimes can be explained by inferring their preservation potential as repositories of early human activity (*e.g.* Mishra *et al.* 2007). This would imply a positive bias: sites have been found in those depositional contexts, and in those corresponding geomorphological settings (*i.e.* topographic depressions: river basins, former lakes, coastal areas), because of specific properties that favor preservation. On the other hand, the work of Goldberg (1995) in the Levant indicates what can

be seen as a negative bias: those landscape features were discontinuous in space and ephemeral in time for most of the Quaternary, hence the gaps in the archaeological signal may be related to the gaps in the geomorphological archive, when the aforementioned landforms were not in existence or they were not active (*e.g.* dry valleys and lakes). Another negative bias is exemplified by the Iberian record, where most of the evidence is associated with the middle terraces of rivers. This probably suggests that, before the time-periods represented by the middle terraces, river behavior was overall too dynamic to allow for the preservation of archaeological material. Interestingly, the latter observation concerns the vast majority of the Iberian river systems, although terrace flights in the interior are better preserved than those of the coastal lowlands (Santisteban and Schulte 2007).

The use of caves appears to have been a marginal and/or chronologically late phenomenon: with very few exceptions (Atapuerca in Spain, Kozarnika in Bulgaria and the caves in the Casablanca area), the use of caves appears in the latter half of the Middle Pleistocene. Again, it is difficult to explain whether this is an artifact of preservation or a consequence of hominin preference on open-air locales, like lake margins and riverine habitats. First steps in testing the preservation argument would be (1) to see how many of the excavated caves preserve earlier deposits (and whether the latter were excavated and proved to be sterile, or not) and (2) to assess how many of those caves were a) in existence for the period under question (*e.g.* Early and early-middle Middle Pleistocene) and b) accessible to hominins (admittedly, a difficult issue to confirm). With regard to the Greek record, the role of caves and rockshelters as both sedimentary archives and landscape features available for habitation, hence as potentially promising areas for investigations, is discussed later in chapter 7; for the purpose of the discussion here and in the following chapters, suffice it to conclude that a lack of cave-sites in the Lower Palaeolithic of Greece would not be surprising.

With regard to chronological frameworks, the following points need to be stressed:

1. Early Pleistocene sites are few and their dating is only rarely uncontested

argued that this boundary holds well also with regard to ecological structuring of landscapes.

2. the number of sites increases in the early-middle Middle Pleistocene, but
3. it is only from the middle and chiefly the latest part of the Middle Pleistocene that the archaeological signal becomes substantiated.

Obviously, this picture is inherently related to the fragmented nature of terrestrial sedimentary archives of the earliest parts of the Pleistocene, and is also associated with the methodological constraints of the available dating techniques and datable materials (*e.g.* Goldberg 1995; Mussi 2001; Santisteban and Schulte 2007). Problematic as they are, it is with those geochronological schemes that archaeologists are building regional chronosequences; it thus has to be appreciated that even the Iberian record, holding now a prominent position in the Eurasian Early Palaeolithic, is by far *based on relative chronologies mostly with regard to fluvial sequences*. Biostratigraphy is a powerful dating tool but it is not devoid of problems and it is often the crux of heated debates. Lithic typology has been -and to some extent is still being- used as a means to 'date' assemblages, a fact that is being repeatedly criticized, hopefully leading to a progressive abandonment of type-fossil approaches.

'Obviously technological evolution, on the other hand, provides more solid grounds for coarse-grained chronological estimations and even a sequencing of assemblages through time, wherever samples are large enough and methodological biases have been excluded. It also assists in identifying patterns of hominin subsistence, land-use and dispersals in space and time and, ultimately, cognitive and social developments; yet, technical systems identified in artefactual assemblages cannot themselves (alone) explain those patterns. Technical strategies reflected in stone tools can be viewed from an evolutionary perspective, but their trajectories are not unidirectional and are driven by multi-causal factors. Hence, in my reading of the circum-Mediterranean evidence, I do not see a justified reason for arguing neither in favor nor against a precedence of 'Mode I' over 'Mode II' assemblages. The earliest (on the current evidence)

dispersals in the Mediterranean appear to involve 'Mode I' assemblages in some records (*e.g.* Iberia); in other records this long-assumed association has been convincingly criticized (*e.g.* for the Italian Peninsula and the Maghreb); in Anatolia there are indications for a very early appearance of 'Mode II' industries; in the Levant, the core-and-flake component at 'Ubeidiya is considered as part of a broader 'Acheulean complex'; and for the material of Kozarnika cave, it is stressed that the core-and-flake industry is not replaced by the Acheulean but "ends directly in the Mousterian/Levallois" (Sirakov *et al.* 2010, 105). Insofar as we accept that (1) there is not any uncontested one-to-one correlation between a hominin taxon and a 'lithic tradition' (let alone that both concepts -hominin taxonomy and lithic traditions- face serious problems with definitions and terminology) (2) the available resolution cannot confirm or falsify any association between specific lithic 'Modes' and separate dispersal events; then, we can only assume multiple, sporadic and discontinuous episodes of dispersals in the peopling of the circum-Mediterranean, as Dennell (2003) suggests for Eurasia in general and Villa (2001) for Italy in particular. Arguably, this sort of patterns cannot be firmly deciphered when their interpretations are implicitly based on lithic evidence that lacks contextual data, exhibits a dubious artificiality or derives from erosional palimpsests, as it is often the case with surface collections; an example of how surface finds may lead to an erroneous construal was given with regard to the alleged 'Pebble Culture' in the area of the Maghreb.

And yet it is mostly surface lithic artefacts that constitute the largest parts of all the records examined here. In lack of stratigraphic control, surface material is endowed with a low time-resolution. Nonetheless, it can still provide first-order indications on human presence/absence and on how the signal for identifying the latter might have been biased by geomorphic agents. Bearing all the above in mind, we can now turn our look into a record that is dominated by surface material and is indeed complicated by tecto-sedimentary perplexities: the Lower Palaeolithic record of Greece.

4 – The Lower Palaeolithic record of Greece

4.1 INTRODUCTION (WITH A SHORT REFERENCE TO THE MIDDLE PALAEOLITHIC)

Unambiguous lithic evidence or human remains dating to the Early and early Middle Pleistocene are so far lacking in Greece. Lithic material that is considered to date to the (late) Middle Pleistocene is scarce and mostly consists of finds that have been chronologically bracketed only in the broadest of terms, with relative dating techniques that are mainly based on the inferred archaic morphology of the artefacts and on usually inadequate stratigraphic correlations. In this light, had the fossils from Megalopolis, Petralona -and perhaps also those from Apidima- never been found, any assertion for a human presence in Greece before the Late Pleistocene would have been only speculative.

In order to assess the validity of this scanty evidence, this chapter aims at providing a critical examination of all reported claims for finds that could be attributed to the Lower Palaeolithic period. Some arguments have been put forth by people who are practicing archaeology on an amateur or semi-professional level, publishing their results in self-funded monographs or semi-popularized archaeology-related journals. As this kind of research is carried out outside the frameworks of academic institutions or the Greek Archaeological Service, the investigators commonly lack the assistance of trained geologists, geomorphologists, palaeontologists or lithic specialists. In effect, their arguments are usually grounded upon their own appreciation of the archaeological context (which is – more often than not – inadequately described), if not solely on the morphology of the artefacts. Thus, although the experience, knowledge and sincere efforts of amateur archaeologists should not be overlooked by the academic community, the way this kind of research is often conducted and pub-

lished renders any re-evaluation considerably difficult (*e.g.* Andreikos 1993; Sarantea 1996). In those cases, either the artefactual character of the finds or the chronological attribution to the Lower Palaeolithic has already been disputed (*e.g.* see Runnels 1995, 708, and Papagianni 2000, 9 for a critique of the two examples of publications cited above).

Meager as the record is, the fact remains that indications for the presence of humans already from the late Middle Pleistocene have been reported from areas that are spread over almost the entire country (Fig. 4.1): the northern parts of Greece (Thrace and Macedonia, section 4.3), the Ionian Islands and Epirus (sections 4.4 and 4.5), up to Central Greece (Thessaly, section 4.6) and the southernmost areas of Peloponnesus (sections 4.2.2 and 4.7); in fact, material that is provisionally ascribed to the Lower Palaeolithic has recently been reported even from the Aegean Islands -from Milos and from places as far as Crete and Gavdos (southernmost Aegean Sea; section 6.4). All of these reports are discussed below, after the examination of the palaeoanthropological testimony (4.2)¹¹. Moreover, a clear emphasis is given here on the finds from Kokkinopilos (Epirus) and Rodia (Thessaly), as these two are the main sites with relatively well-documented stratified occurrences. But before assessing case-by-case the arguments for Lower Palaeolithic remains, it is deemed fruitful to consider first the main characteristics of the Late Pleistocene record of Greece, namely that of the Middle Palaeolithic.

Compared to the highly fragmentary character of the Lower Palaeolithic data set (see below), the Middle Palaeolithic record of Greece is more solid and con-

11. The hominin fossil from Megalopolis is discussed in section 4.7.2 together with the archaeological evidence from this area.

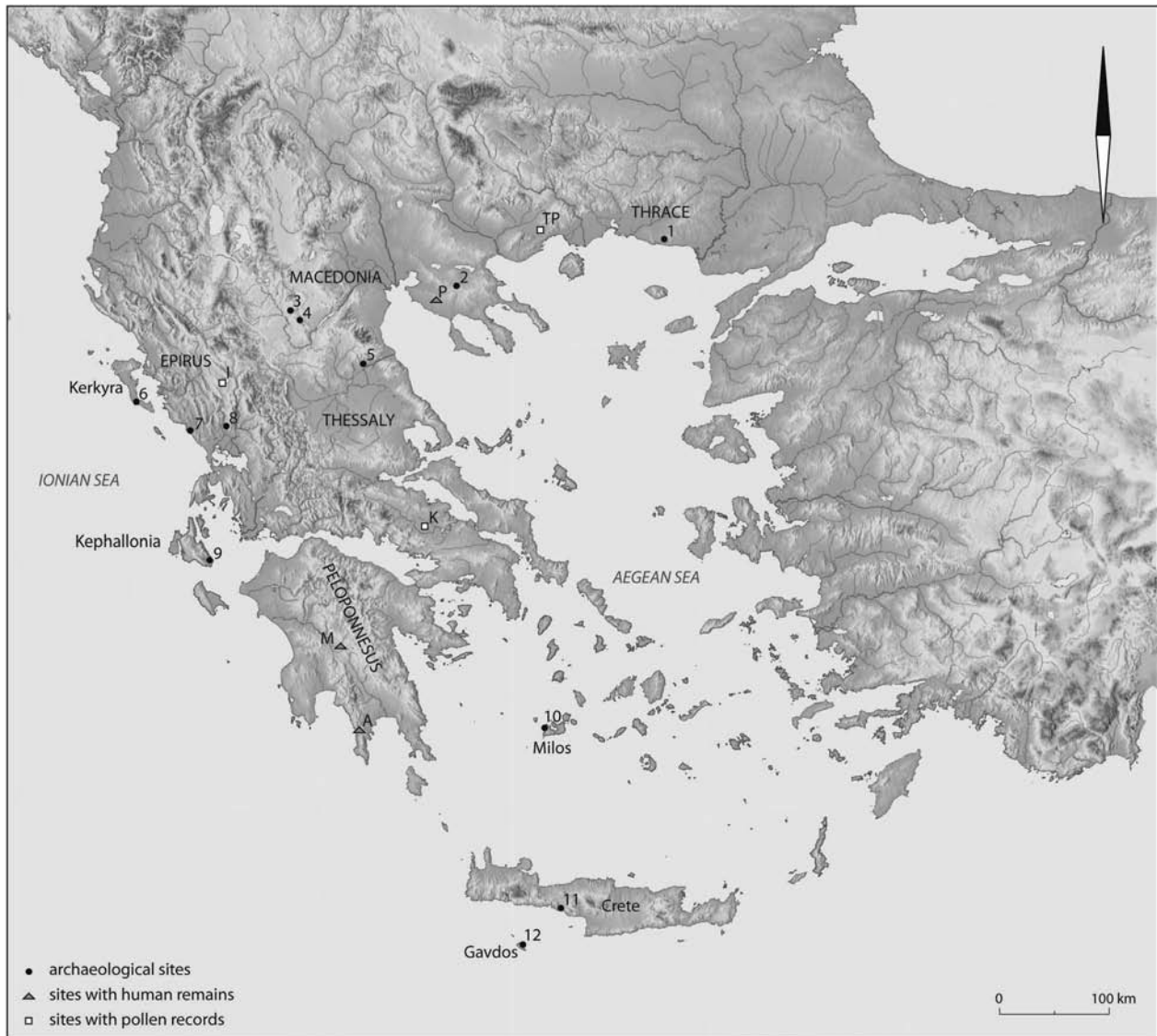


Fig. 4.1 Map of Greece showing key sites examined and discussed in this study. Archaeological sites: 1) Petrola 2) Dombia 3) Siatista 4) Palaeokastro 5) Rodia 6) Korissia 7) Alonaki, Ormos Odysseos 8) Kokkinopilos 9) Nea Skala 10) Triadon Bay 11) Preveli 12) Gavdos. Sites with human remains: P = Petralona Cave; M = Megalopolis; A = Apidima Cave. Sites with pollen records: TP = Tenaghi Philippon; I = Ioannina; K = Kopais

tinuous, yet poorly dated and hitherto not sufficiently documented. Nevertheless, since the onset of the first systematic explorations in the 1960's (for reviews see Kourtessi-Philippakis 1986; Darlas 1994; Runnels 1995; Papagianni 2000), fresh approaches and new perspectives – often aligned with the introduction of methodological and technological advances in archaeological practice – have improved not only the number of known sites, but also their interpretation

(e.g. see papers in Bailey 1997 and Bailey *et al.* 1999; Papagianni 2000; Panagopoulou *et al.* 2002-2004; Richards *et al.* 2008). Then again, despite the fact that Middle Palaeolithic findspots have been routinely identified during nearly all survey projects of the last three decades, few of the *ca.* two hundred open-air Middle Palaeolithic sites and findspots (Harvati *et al.* 2009) have yet been excavated. Moreover, it is only in but a handful of the open-air sites that the

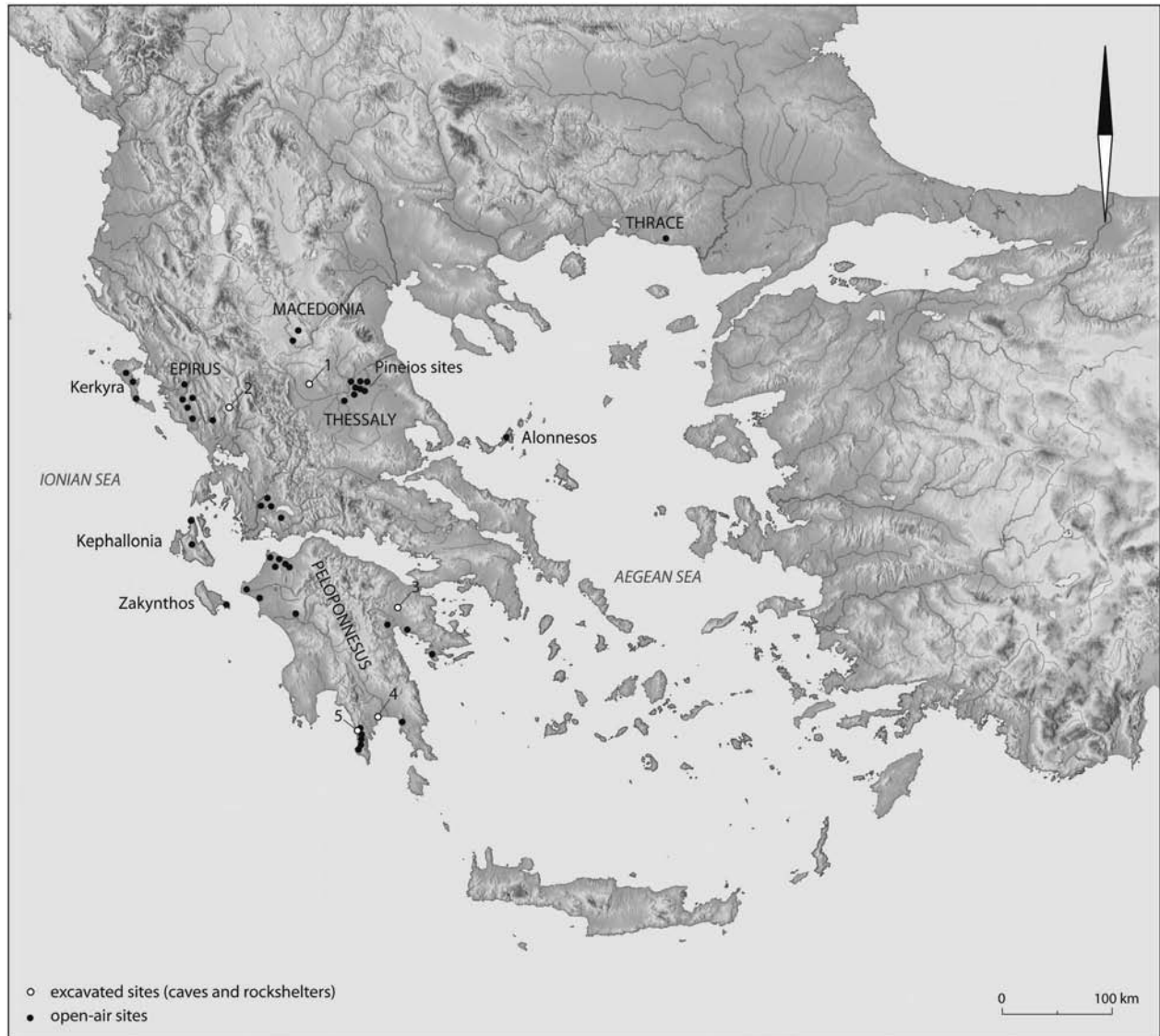


Fig. 4.2 Main Middle Palaeolithic sites of Greece: 1) Theopetra 2) Asprochaliko 3) Kleisoura 4) Lakonis 5) Kalamakia

material considered as of Middle Palaeolithic age has been identified as such on the basis of chronostratigraphic criteria, whilst sites with radiometric dates are even fewer (for notable exceptions see for example Pope *et al.* 1984, and Runnels and van Andel 1993a, 2003). As a consequence, the backbone of the Greek Middle Palaeolithic is essentially restricted to only five cave sequences that have been excavated and are bracketed chronologically with absolute dates, albeit not enough and in cases not unproblematic (Fig. 4.2).

The cave of Asprochaliko was excavated by Higgs and Vita-Finzi (1966) and was for long considered (erroneously) as the reference-site for describing Mousterian variability in Greece (Papakonstantinou and Vassilopoulou 1997; Darlas 2007). Its basal Mousterian levels yielded abundant laminar Levallois products and are dated to *ca.* 90-100 ka by a single TL date (combined measurement on two heated flints; Huxtable *et al.* 1992; Gowlett and Carter 1997), whilst the upper Mousterian industry, dominated by small-sized pseudo-Levallois points, is tentatively dated by ^{14}C to *ca.* 40 ka (Higgs and Vita-

Finzi 1966; Bailey *et al.* 1983; 1992). In central Greece, the Middle Palaeolithic levels in the cave of Theopetra (Kyparissi-Apostolika 2000) document a wide diversity and flexibility in reduction strategies associated with the Levallois technique (Panagopoulou 1999); moreover, the industry includes also a unifacial flake cleaver (so far a unique find in Greece), a cordiform biface made on an 'exotic' raw material, as well as a few chopping tools (*ibid.*). The sequence was originally dated by ^{14}C to 45-33 ka. Recent re-dating of these levels by TL on burned flints yielded coherent results, which place the first human occupation of the cave at the transition from MIS 6 to MIS 5 and more probably the last interglacial itself (Valladas *et al.* 2007), since plant remains from the same strata indicate a mild climate, in accordance with a lack of freeze-thaw sedimentary features that characterize the rest of the sequence (Ntinou 2000; Karkanas 2001). On the basis of these new dates, Theopetra has so far yielded the oldest dated deposits with stratified Middle Palaeolithic artefacts in Greece. Noteworthy is also the preserved footprints at Theopetra: they probably belong to a (Neanderthal?) child, they are associated with Mousterian lithics, and one of them is assumed to have been made by a covered foot, in which case it would be the oldest evidence of footwear (Manolis *et al.* 2000).

The rest of the excavated caves are located in Peloponnesus. The Middle Palaeolithic layers of the cave of Kleisoura, in Argolid, are as yet undated; they have yielded a few bifacial implements, but notable is the fact that a blade-based technology co-occurs in the lower layers with specimens made on flake blanks, and is overlain by artefacts of discoidal and Levallois character in the upper layers (Koumouzelis *et al.* 2001; Sitlivy *et al.* 2007). The caves of Lakonis and Kalamakia are situated in close proximity on the Mani Peninsula and they are formed as part of the karstic system of the area, which includes also the cave of Apidima (see 4.2.2 below). The sequence at Kalamakia is considered to begin in the early part of the last glacial (at *ca.* 100 ka) on the basis of the identification of beach deposits that underlie the first archaeological layers and have been attributed to MIS 5c, whilst a single ^{14}C (AMS) date on charcoal from the last artefact-bearing layer provides an upper limit for the human occupation of the cave at around 40 ka; so far there are no reliable dates available for

the different layers of the sequence (Darlas and de Lumley 1999; Darlas 2007, 357). Hominin fossils that have been discovered at Kalamakia (an upper M^3 and six more teeth, cranial fragments, a fragment of a fibula and a lumbar vertebra) are seen as Neanderthal remains (Darlas 2007) and a more detailed description is currently in preparation (Harvati *et al.* 2009, 139). In contrast to the rare presence of discoidal cores, the Levallois technique is well-represented at Kalamakia, but the technological methods applied are thought to follow the constraints imposed by the raw materials, which include a type of andesitic lava (prevailing also at Lakonis), flint, quartz and quartzite (Darlas 2007). Affinities with Kalamakia, in terms of the raw materials, the identified ungulate species of the fauna and probably also in the technological strategies of the reduction sequence, can be found in the neighboring site of Lakonis (Panagopoulou *et al.* 2002-2004). The sequence of Lakonis I at the eponymous cave complex begins at around MIS 5e, according to U-series dates (two samples from the bottom of the stratigraphy) and ends at *ca.* 40 ka, on the basis of radiocarbon/AMS (six samples from the upper levels), whilst TL and OSL results are pending (*ibid.*, 331; Elefanti *et al.* 2008). The collapsed cave at Lakonis I preserves deposits of almost exclusively anthropogenic origin, with extremely high densities of archaeological remains that find no parallels elsewhere in Greece and are perhaps only comparable to the assemblages of Blombos Cave in south Africa (*ibid.*, 343; Elefanti *et al.* 2008). Lakonis is a 'multiple activity site' with *in situ* hearth complexes and great inter- and intra-assemblage variability throughout its stratigraphic units, a predominance of Levallois (laminar, recurrent, centripetal) in the Middle Palaeolithic assemblages, but also with non-Levallois technological elements (discoidal, Quina, prismatic), as well as a small percentage of bifacial tools. Importantly, Lakonis is one of the few sites in Eurasia where Neanderthal remains (in this case, a lower M^3) have been found in an undisturbed context associated with an Initial Upper Palaeolithic industry, dated at Lakonis to *ca.* 44-38 radiocarbon ka (Harvati *et al.* 2003; Panagopoulou *et al.* 2002-2004; Elefanti *et al.* 2008; Harvati *et al.* 2009). Moreover, measurements of strontium isotope ratios from the Lakonis tooth provided the first direct evidence for Neanderthal mobility, by demonstrating that the individual represented by the M^3 lived for some time in a

region 20 km (or even further) away from the site of Lakonis (Richards *et al.* 2008).

Whereas Lakonis and Kalamakia would have been situated close to the coast at the time of their occupation, Theopetra, Asprochaliko and Klisoura are inland sites, although the latter is also not far from the coast (Fig. 4.2). Furthermore, all of the cave-sites described above occur in low altitudes, namely below *ca.* 300 m asl, and the open-air sites discovered so far appear to follow this altitudinal pattern, at least in their majority. A notable exception regards the Middle Palaeolithic open-air findspots discovered on the highland plateaus of Grevena, at altitudes above 1000–1500 m (Efstratiou *et al.* 2006).

Most of the open-air sites are associated with either coastal or lowland riverine geomorphological and depositional settings, *i.e.* mainly coastal (often alluvial) plains, fossilized sand dunes, marine terraces and beach deposits for the former category (*e.g.* Servais 1961; Leroi-Gourhan 1964; Chavaillon *et al.* 1967, 1969; Sordinas 1969, 1970; Cubuk 1976; Reisch 1982; Kavvadias 1984; Darlas 1994, 1995a; Runnels *et al.* 1999) and river valleys, alluvial fans and -mostly- fluvial terraces for the latter (*e.g.* Milošević *et al.* 1965; Runnels 1988; Runnels and van Andel 1993b; Darlas 1999; Panagopoulou *et al.* 2001). Next to those are, in rather considerable numbers, sites which are situated within karst settings, for instance in karstic basins associated with *terra rossa* fills (*e.g.* Dousougli 1999; Papagianni 2000; Runnels and van Andel 2003; see also 4.5 below), or on plateaus (*e.g.* Efstratiou *et al.* 2006). With a few exceptions regarding chiefly fluvial deposits (*e.g.* Milošević *et al.* 1965), faunal remains are conspicuous by their absence from the lists of finds, whereas lithic artefacts are almost always being discovered from the surfaces of Pleistocene landforms. In the rare cases where artefacts have been found stratified, they are commonly associated with paleosol horizons (*e.g.* Pope *et al.* 1984; van Andel 1998; Runnels and van Andel 2003) or river terrace deposits (*e.g.* Milošević *et al.* 1965; Runnels and van Andel 1993b). Finally, in marked contrast to the wealth of Middle Palaeolithic evidence from coastal, fluvial and karst settings, there are hardly any sites reported from lacustrine depositional settings; exceptions would include the undated and largely non-diagnostic artefacts found as-

sociated with fluvio-lacustrine sediments at the margins of the Megalopolis palaeo-lake, which are discussed separately below (4.7.2), a chopper found close to the lake Korissia in Corfu (section 4.4.2), and a brief report on Levallois implements discovered on the surface of sediments that probably belong to a palaeoshore of Lysimachia lake in Aetoloakarnania (Papakonstantinou 1991). On the other hand, the *terra rossa* deposits of the numerous karst depressions occurring in north-west Greece and some Ionian Islands were accumulating in the sub-aqueous environments of ephemeral lakes formed within the depressions; in that respect, these are also lacustrine depositional settings *sensu lato*.

With hardly any exceptions, all of the Middle Palaeolithic open-air sites are related to landforms of generally low gradients¹². Clearly, this is the overall result of the combined effects of the altitudinal norm mentioned earlier (because the steepness of the relief is positively correlated with altitude; see 6.5) and the aforementioned prevailing types of geomorphological and/or depositional environments: for instance, coastal areas, palaeo-floodplains and karst plateaus commonly display a gentle relief. Another point that needs to be stressed is that almost none of the open-air Middle Palaeolithic sites have been reported to be associated with landforms *predating the last interglacial*.

This short overview of the Greek Middle Palaeolithic deserves one last comment with regard to the raw materials that were in use during this period. On the current evidence from both the excavated caves and the open-air sites, the raw materials were commonly derived from primary or secondary sources of local origin, usually not further than *ca.* 10–20 km away from the sites, hence in line with the evidence from other European sites (*e.g.* Féblot-Augustins 1999; but see Karkanas *et al.* 2008 for a distance of 5–50 km at Theopetra). Nevertheless, detailed studies of

12. This can be easily seen if one plots the discovered sites on a slope map, or even on a base-map of relief. However, this is a general assessment that aims to underline the prevailing pattern in the distribution of open-air Middle Palaeolithic sites in relation to the relief; in that respect, it does not take into account exceptions that would arise *e.g.* according to the micro-topography at each site.

raw material transport distances are overall lacking in Greece and in most of the cases where 'exotic' materials have been documented, their provenance is yet to be elucidated. The prevailing raw material is flint, occurring in various types and varying degrees of quality (its coarse-grained versions often described as 'chert'), followed by quartz, quartzite, schist, and volcanic materials such as that found at Lakonis and Kalamakia. In some instances, it has been suggested that high-quality raw materials are being selected for (imported?) Levallois blanks, whilst coarser materials are used for artefacts that are less heavily (and more irregularly) re-sharpened and frequently non-Levallois in technology (*e.g.* Gowlett 1999).

In sum, the Middle Palaeolithic of Greece is largely composed of undated and commonly non-provenanced lithic assemblages from open-air sites that lack the necessary contextual information, while problems are extended to the excavated sites as well. With Theopetra being re-dated to *ca.* 130 ka, due to the scarce radiometric dates the rest of the sites are variously (and, more often than not, tentatively) dated to between 100 and 40 ka. One of the most profound characteristics of this period is a marked variability in the applied technological strategies of tool manufacturing, and hence also a morphological diversity in the tool inventories (Panagopoulou *et al.* 2002-2004, 344). The Levallois method appears to be omnipresent, albeit in various frequencies, and yet non-Levallois methods are almost equally frequently encountered (*cf.* Darlas 2007). Be it synchronous or diachronic, this local or regional, inter- and/or intra-site diversity and flexibility in reduction processes (*e.g.* Panagopoulou 1999) may reflect 'cultural-stylistic' variation, functional variation, raw material constraints, differential subsistence patterns (*e.g.* degree of mobility), cognitive abilities, social regimes, or combinations of all of the above (*e.g.* Gowlett 1999; *cf.* Dibble 1991, and Bar-Yosef and van Peer 2009). Additionally, this variability/diversity may be seen as mirroring the environmental diversity and the mosaic character of the Greek landscapes (Panagopoulou *et al.* 2002-2004), but nonetheless, the small sample of well-documented sites and the current chronological resolution precludes any conclusive interpretations.

If the Greek Middle Palaeolithic chipped stone technology and morphotypes emerge in a somewhat 'in-

homogeneous fashion', the same could be expected for its Lower Palaeolithic predecessors, since non-uniform, rather opportunistic and non-standardized technological applications are thought to be the trademark of the latter period. That would in turn pose immense difficulties to those who choose to rely on a 'type-fossil approach'; it would conversely emphasize the need for more rigid analytical procedures in characterizing assemblages. All things considered, it is against this largely fragmentary, highly variable and still enigmatic Middle Palaeolithic background that any purported 'pre-Mousterian' evidence needs to be distinguished from and, if possible, compared with.

4.2 THE PALAEOANTHROPOLOGICAL RECORD

4.2.1 Petralona

In 1960, local villagers discovered a cranium (Fig. 4.3) in the Petralona cavern, which is situated at the north-west margin of the Chalkidiki peninsula (North Greece; for the location of the site see Fig. 4.1). The cavern was tested by excavation in a small area during 1974-1981, but the published results of the excavations (*e.g.* Poulanos 1980, 1982) have provided imprecise and contradictory accounts on the stratigraphy, the associated faunal assemblage and the reported existence of postcranial remains related to the skull (Stringer 2000a; Galanidou 2004). Due to uncertainties surrounding both the circumstances of discovery and the excavator's publications, it is unclear whether the skull was found lying on the flowstone that covers the floor of the chamber or on a layer underlying the flowstone (Grün 1996). The skull is encrusted with calcite (*ibid*) and, most probably, it was stuck (by the calcite flow) against the wall of a diverticule (Darlas 1995a). Nevertheless, the original stratigraphic position of the specimen is unknown; hence it cannot be correlated with any of the twenty-seven layers that have been identified in the deposits of the cave (*ibid*). As a consequence of all the above, a debate continues about the age of the cranium and its taxonomic identity.

Petralona is one of the richest palaeontological caves in Europe, containing abundant remains of both herbivores and carnivores (Tsoukala 1991), although the excavated fauna has not been specified for each stra-



Fig. 4.3 The Petralona cranium. The photograph was provided from and is copyrighted by the Laboratory of Geology and Palaeontology, University of Thessaloniki

tigraphic level (Darlas 1995a, 52; for faunal lists see Kretzoi and Poulianos 1981; Tsoukala 1991; for a summary of those lists see Darlas 1995a). The analysis of the large mammal faunal material distinguished two main groups (Tsoukala 1991): the first one is of early Middle Pleistocene age, possibly bracketed between *ca.* 500-700 ka (Darlas 1995a); the second group includes species of the Late Pleistocene, as well as some transitive taxa from the latest Middle and Late Pleistocene (Tsoukala 1991, 335). Finally, according to Stringer (1983, 734), the bone fragments that were once published as part of human postcranial remains (Poulianos 1980) were not identified as human by any of the anthropologists who examined them; in the same vein, Tsoukala's study of the fauna (1991, 333) did not yield any evidence for the existence of hominin remains.

Lithic material is also reported to be abundant (Poulianos 1982), but it has not been published properly and only some drawings and pictures of a few artefacts are available (Darlas 1995a, 53). Darlas (*ibid*) reports that the industry is mainly made on quartz

and it is dominated by tools made on debris and only rarely on flakes, whereas pebble tools are rare and handaxes are absent. In contrast, Harvati *et al.* (2009) doubt the artefactual status of the published material. Indeed, considering the published drawings, as well as the morphology of the pieces which are on display at the local 'museum' (personal observation), the artificiality of the material from Petralona should be dealt with caution.

The cranium is exceptionally well-preserved, lacking only the incisors, the right zygomatic arch and possibly the mastoid processes (Stringer *et al.* 1979). Since its discovery, the taxonomic classification of the specimen has entailed various assignments, but most of which considered it as representative of a species classifiable between *Homo erectus* and *Homo sapiens*, perhaps belonging to a variant of the Neanderthal lineage or to 'archaic *H. sapiens*' (*e.g.* Stringer *et al.* 1979; Wolpoff 1980; Stringer 1983). The unsatisfactory term 'archaic *H. sapiens*' was for long used to describe fossils such as the Petralona cranium and those from Kabwe (Africa) and Dali (Asia), dating to between 500/400 and 200 ka and exhibiting both primitive, *erectus*-like traits and more 'progressive' ('incipient Neanderthal') features (Stringer 1992). More recently, there is a sort of consensus in interposing a distinct species, *Homo heidelbergensis*, between *H. erectus* (or its African variant *H. ergaster*) and *H. neanderthalensis* (in Europe; in Africa it would be *H. sapiens*), most probably as an (African-)European taxon that is the last common ancestor of Neanderthals and anatomically modern humans (*e.g.* Manzi 2004; Klein 2009; Mounier *et al.* 2009; see also Harvati 2009 for a recent evaluation of the Petralona cranium with regard to other African and European Middle Pleistocene fossils, and compare with Bermudez de Castro *et al.* 1997). In this line, the Petralona cranium would now be included within the grade of *H. heidelbergensis* (Galanidou 2004; Harvati *et al.* 2009).

The Petralona specimen is essentially a 'surface find' without reliable provenience data; hence the long-lasting controversy around its dating (*e.g.* see the correspondence in the journal *Nature*, vol. 299 (issue 281) between A. Poulianos, I. Lyrizis, M. Ikeya and G. Henning *et al.*; for a review see Wintle and Jacobs

1982; and also Latham and Schwarz 1992)¹³. Lacking a position in the stratigraphy, the cranium cannot be associated with the faunal remains, and it was early on demonstrated that any age estimate based on the 'faunal chronology' is misleading (Grün 1996, and references therein). Many of the absolute dating assays with ESR, TL and U-series techniques have also proved to be untrustworthy or controversial (Wintle and Jacobs 1982). The most reliable dates should be those regarding the calcite layer(s) encrusting the skull, which were derived by ESR measurements (Hennig *et al.* 1981). The latter dating results were later reassessed, concluding that the age of the skull is bracketed between about 150 and 250/350 ka (Grün 1996; see also Latham and Schwarz 1992 for a re-analysis of the calcite with Uranium series, chiefly confirming the ESR estimate of 150 ka as the minimum age).

4.2.2 Apidima

The Apidima cave complex is situated in the western coast of the Mani Peninsula, between the Gulfs of Lakonia and Messene, on the southernmost part of Peloponnesus (Fig. 4.1). On the steep cliffs along the coasts of Mani, many of the numerous caverns and cavities that have been formed in the limestone bed-rock preserve Quaternary deposits, often containing also archaeological remains, but only a few of them are accessible and/or have escaped erosion (Darlás and de Lumley 1999). Quaternary terrestrial sediments are usually to be found in the form of cemented -and frequently fossiliferous- breccias, or as scree and talus cones (Tsoukala 1999).

The site of Apidima was excavated between 1978 and 1985, it comprises four caves (A to D) and has so far yielded some 30,000 cultural and faunal finds, including human remains that are thought to belong to 6-8 individuals (Pitsios 1999). The caves are at 4

to 24 m asl and their continental fossiliferous deposits display today an irregular configuration, which continues also underwater (Pitsios 1979, 1996). This fragmentary preservation is explained as the result of at least two former sea-level fluctuations that have caused extensive erosion of the stratified sediments; it has thus been estimated that only less than 5% of the original volume of the Pleistocene deposits has escaped the erosive action of the waves, which have washed out most of the Pleistocene layers (Pitsios 1996).

Nonetheless, two human crania were found in 1978 in cave A: the 'Apidima I' skull (LAO 1/S1) was discovered in situ, exposed on the surface of a breccia pocket, wedged between the walls of the cave. The second skull, 'Apidima II' (LAO 1/S2) was later found adjacent to the first cranium, while a block of the breccia was being extracted for laboratory cleaning (Harvati and Delson 1999). The Apidima II cranium is better-preserved than Apidima I, which is less complete and has only recently been cleaned (Harvati *et al.* 2009). Although the site and the crania are of significant importance for the palaeoanthropology of Eurasia, the results of the excavations and the data on the human remains have been published only as preliminary descriptions and short communications (*ibid.*, 137). At yet, there are no 'absolute' dates for the skulls.

The excavator of the site, palaeoanthropologist Th. Pitsios, classifies both crania to archaic forms of *H. sapiens* ('pre-Neanderthals'), and on the basis of the geological context and the morphology of Apidima II, he has suggested that the skulls should be placed chronologically between 100 and 300 ka (Pitsios 1996). During an international conference on the 'Palaeoanthropology of the Mani Peninsula', Apidima II was compared to the Petralona cranium, and Pitsios pointed out that the two skulls share many affinities, although the one from Apidima is more gracile (Harvati and Delson 1999). Similarities with Neanderthal features were also noted and most of the participants agreed that there are some facial characteristics which seem to be clearly Neanderthal-like, albeit not in the fully derived classic morphology (*ibid.*, 345). On the other hand, the researchers also commented on the pronounced prognathism of Apidima II, which is comparable to that of some of the Middle Pleisto-

13. Until the discovery of the crania at Sima de los Huesos, the Petralona skull was the most complete European Middle Pleistocene specimen (Harvati 2009). This status, as well as the fact that it possibly represents a species which could be regarded as the last common ancestor of Neanderthals and anatomically modern humans, has resulted in a list of relevant publications numbering more than two hundred and twenty papers; needless to say, only a few of those have been cited here.

cene remains from Atapuerca (ibid, 344). Recently, Harvati and colleagues (2009) used multivariate statistical analysis to compare facial measurements of Apidima with those from a sample of other relevant fossils (four *H. heidelbergensis*, five Neanderthals and four early modern humans); the principal components (PC) analysis showed that Apidima II falls near the Neanderthal and *H. heidelbergensis* ranges, with its PC 1 score being most similar to that of Petralona and PC 2 nearest the fossils from Kabwe, Arago and Guattari (ibid, 137 and figure 6). Commenting on the 'incipient' Neanderthal facial traits of Apidima II, Harvati *et al.* (2009, 137) suggest that “the Apidima crania might fit into the early part of the temporal trend observed in the European Neanderthal lineage according to the accretion hypothesis of Neanderthal evolution”.

The study of the large mammal faunal remains distinguished between two main assemblages, one of middle to late Middle Pleistocene age, and one dating to the Late Pleistocene (Tsoukala 1999). The fauna is stratigraphically mixed (ibid), and, although it has been suggested that the crania-yielding breccia could be related to the Middle Pleistocene faunal group, there are no fossils securely associated with the breccia (Harvati and Delson 1999). Similar problems apply to the lithic material: Kourtessi-Philippakis' preliminary study indicates that the artefacts from cave A belong to a Middle Palaeolithic assemblage, but their association with the breccia of the crania is uncertain (ibid). A Middle Pleistocene date has nevertheless been evoked for that breccia also on the grounds of geomorphological observations, whereas ESR dating of beach deposits at different elevations indicates ages of 40, 80 and 200 ka, with the latter age possibly correlated to the breccia of cave A (Harvati and Delson 1999, 348).

In sum, the hominin crania are considered to date to the Middle Pleistocene mainly on the basis of their archaic morphology, as well as on geomorphological and stratigraphic considerations (Harvati 2000; Harvati *et al.* 2009). The faunal and lithic material may be seen as providing at best *indications* in support to any chronological estimate and should be treated with caution. Clearly, apart from the much-awaited further clarification of the taxonomic identity of the

crania, radiometric dates are needed for the refinement of their chronological bracketing.

4.3 NORTH GREECE

4.3.1 Thrace

Until the 1990's, the province of Eastern Macedonia and Thrace remained virtually a blank spot on the Palaeolithic map of Greece (Ammerman *et al.* 1999), although it forms a natural corridor in the assumed routes of animal and human dispersals, from both east-to-west and north-to-south. The presence of (Lower) Palaeolithic sites in other Balkan countries to the north, the cave of Petralona in the neighboring Chalkidiki Peninsula to the west, as well as the cave of Yarimburgaz and the numerous sites of the Bosphorus region, directly adjacent to the east of Thrace (Runnels 2003b), altogether underline the importance of the region, highlighting at the same time the paucity of research here.

The prospects of this area for Palaeolithic investigations are also reflected in the fact that it hosts some of the largest Neogene/Quaternary basins in Greece (see also sections 6.3 and 6.4). The three major depressions, namely the basins of Vardar-Axios-Thermaikos, Struma-Serres-Strymon and Nestos-Thasos-Samothraki, are filled with sedimentary sequences of fanglomerates, conglomerates, sandstones and fine clastics, which overall represent complex tecto-sedimentary histories of changing palaeoenvironmental regimes and alternating terrestrial to fluvio-lacustrine depositional settings (Psilovikos and Syrides 1984). Continental zones would have been relatively extensive during the Late Pliocene-Early Pleistocene, whilst subsidence associated with the activity of the North Aegean Trough during the Middle Pleistocene resulted in marine transgressions (from MIS 9 and onwards, Lykousis 2009), the forming of new grabens and the rejuvenation of the relief, alongside a predominantly fluvio-lacustrine sedimentation (Psilovikos and Syrides 1984; Roussos and Lyssimachou 1991; Rondoyianni *et al.* 2004). During the Early and Middle Pleistocene that is of interest here, extensive deltas, lagoons and estuaries were formed, with lakes, marshes and shallow beaches occurring side by side. As discussed further below, such environments are considered to have been

highly productive in terms of water and plant resources, hence attracting both animals and humans. Unfortunately, the greatest portion of the former vast coastal plains and fluvial lowland settings are now either submerged or buried by thick fluvial and fluvio-lacustrine sequences (*e.g.* see Stanley and Perissoratis 1977 for estimated thicknesses). Overall, the northern Aegean presents the highest subsidence rates for the Quaternary (Lykousis 2009), and wherever sedimentation kept pace with subsidence, large amounts of clastic sediments from the hinterland transported by the main rivers (Axios, Strymon, Nestos) filled the depressions rapidly, thereby rendering the older deposits inaccessible today. On the other hand, Pleistocene outcrops do exist, exposed by modern activities (*e.g.* quarries) or natural causes, as with the case of rivers that have incised through the sedimentary infills of the basins. After all, the potentials of this region for future discoveries are reflected also in the presence of important palaeontological sites (*e.g.* Tsoukala 1991; Koufos 2001; Athanassiou and Kostopoulos 2001).

Although the first systematic survey in the region had a primary focus on the later prehistory (Neolithic and Bronze Age), a number of open-air Palaeolithic sites were identified, as the project included also geomorphological investigations and a special attention to Pleistocene formations (Ammerman *et al.* 1999). In the targeted area (Krovili, Rhodope province), the two most important findspots were found on Pleistocene terraces, in close proximity to the 'Graben of Petrota' (Efstratiou and Ammerman 1996; see Fig. 4.1 for location). The latter is an impressive outcrop of silicified rock of volcanic origin, which was exploited as a source of raw material throughout different periods, including the Neolithic and modern times (*ibid.*). On the basis of techno-morphological characteristics, the lithic material from both findspots has been attributed to the Middle Palaeolithic, and it includes also a small biface with a thick base and a thinned tip (Ammerman *et al.* 1999). At the same location of the biface, a collection of quartzite artefacts allowed the researchers to assume that the site may represent also cultural phases earlier than the Middle Palaeolithic, noting that "at any rate the combined presence of core tools (choppers and chopping tools) and of quartzite flakes indicates that this collection may include earlier material as well as material of

Middle Palaeolithic date as suggested by the other artefacts" (*ibid.*, 214). Noteworthy, it is also stressed that the valley in which the findspots are located would have hosted small lakes and swamps with freshwater resources, whereas the nearby 'Graben of Petrota' would have offered itself as a readily accessible source of raw material for the production of lithic implements (Efstratiou and Ammerman 1996).

Evidently, the province of Thrace and Eastern Macedonia still lacks solid evidence for a Lower Palaeolithic human presence, but the results from the first systematic exploration of the region can already be seen as promising indications for future research.

4.3.2 Macedonia

In 1963, a handaxe was discovered by a local villager in a locality close to Palaeokastro in Western Macedonia, and was later delivered to E. Higgs who was by that time surveying Epirus and Macedonia with a team from Cambridge (Higgs 1964; Dakaris *et al.* 1964). The artefact (Fig. 4.4) is an elongated amygdaloid biface (length: 15.3 cm; width: 9.6 cm; thickness: 3.1 cm; platform thickness 3.4 cm; all measurements taken by the author according to the criteria of Debénath and Dibble 1994). It has a green colour and Higgs reports that it is made from trachyte (1964, 54); the raw material is certainly a volcanic rock, but probably a type of peridotite (P. Karkanis, pers. comm. while inspecting the specimen in 2005), perhaps dunite, which is the type of rock outcropping at the locality (as indicated also in the geological map of the area).

In this locality, high-level fluvial gravels have been deposited about 60-90 m above the present valley floor, and Higgs suggested that the artefact may have been derived from these gravels (in Dakaris *et al.* 1964). Indeed, the base of the artefact has been left unworked, thereby retaining the cortex, and a careful inspection with a magnifier reveals clear signs of the type of battering that is characteristic of fluvial transport. In 2005, I visited the location that is reported as the findspot of the handaxe, as part of the team of the Aliakmonas Survey Project (see 5.2 below). We were able to confirm the presence of extensive outcrops of the volcanic rock that was used as raw material for the handaxe, but it was not possible to make any as-

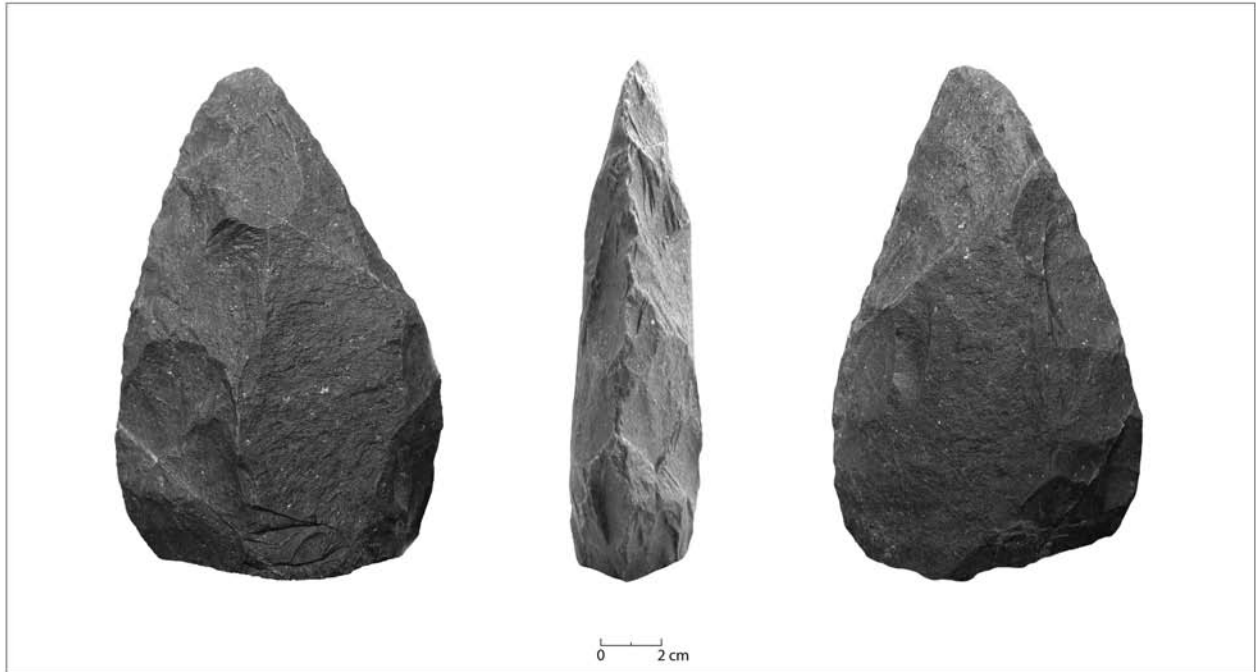


Fig. 4.4 The handaxe from Palaeokastro

assessment regarding its provenance. Consequently, the handaxe remains essentially a 'stray find'.

Higgs did not present any arguments in support to an attribution of the artefact to the Lower Palaeolithic period, nor did he explain the assumption that it derives from the fluvial gravels. Apparently, the very same fact that it is a handaxe (and in fact the first one ever found in Greece) was considered self-explanatory for its presumed Lower Palaeolithic age. Since then, the existence of this specimen has been cited in the literature as (a more or less solid) evidence for a human presence in Greece since the Lower Palaeolithic. The specimen is indeed a typical Acheulean handaxe, but it is an isolated, surface find without sufficient data concerning its provenance, hence lacking a contextual framework that would potentially allow for a chronological bracketing. Therefore, it should be regarded as an *indication* for a human presence during the Lower Palaeolithic, rather than as sound evidence.

Other lithic artefacts of probable Lower Palaeolithic age from Western Macedonia have been collected from several localities on the terraces of the Aliakmon River, but the material discovered so far is too

few to substantiate claims on the existence of Lower Palaeolithic sites or even lithic 'industries' (Daras 1994)¹⁴. The largest collection was discovered near Siatista (*i.e.* close to Palaeokastro; Fig. 4.1), it was found on the middle terrace of the river and comprises of tools made on flakes, denticulates and notched pieces (*ibid.* 310). All the same, the material is again undated and any attribution to the Lower Palaeolithic should be considered as only suggestive, if not tenuous.

Finally, mention should be made of the recent discoveries from a regional survey in the area of Langadas, close to Thessaloniki (Andreou and Kotsakis 1994). At the locality of Doumbia (see location in Fig. 4.1), lithic implements made on locally-available milky quartz were found associated with a Pleistocene alluvial fan; the material belongs essentially to a core-and-flake industry, with choppers, chopping tools, denticulates and notched pieces, and the techno-morphological characteristics of the artefacts are

14. The account presented here excludes the material found during the 'Aliakmon Lower Palaeolithic Survey Project', which is discussed separately in section 5.2.

considered to allow comparisons with those from Rodia (Thessaly) and Yarimbuzguz (Turkey) (C. Runnels, pers. comm. 2007). The researchers note that this is a surface collection and the mixing of artefacts from different periods cannot be excluded; moreover, in attributing the artefacts to a cultural period, they prefer to use the term Early Palaeolithic to describe specimens/assemblages such as that from Doumbia, which could be classified under the conventional term of 'Lower Palaeolithic', or alternatively could be seen as a different and/or early facies of the regional Middle Palaeolithic technological tradition (Runnels, pers. comm. 2007).

Notably, the sub-basin of Doumbia, where the site is located, belongs to the wider basin-complex of Pro-Mygdonia, which was filled with fluvio-terrestrial and lacustrine sediments during the early Pleistocene and was later broken-up to smaller basins (Mygdonia, Zagliveri, Marathousa, Doumbia) due to tectonic activity at the end of the early Pleistocene. The largest of all, the Mygdonia basin, hosted a lake that was gradually drained during the middle-late Pleistocene, and the remnants of this palaeo-lake are present today as the lakes of Langadas and Volvi (Koufos *et al.* 1995). Several mammalian localities have been found in the wider Mygdonia basin, including the late Villafranchian site of Apollonia 1 (*ibid.*). The fauna discovered in the latter site includes remains of the saber-tooth *Megantereon whitei* (Martínez-Navarro and Palmqvist 1996). This is an African taxon that dispersed into Europe at around the Pliocene-Pleistocene boundary, and it is also found in Dmanisi (Georgia) and Venta Micena (Orce, Spain; *ibid.*). *M. whitei* is found together with some species of ungulates, together forming an assemblage that marks a faunal turnover at the end of the Villafranchian (*e.g.* Kostopoulos *et al.* 2007) and is considered to be possibly related to the first arrival of hominins in Europe (Martínez-Navarro and Palmqvist 1996). Particularly, *Megantereon* is a hypercarnivorous felid that would have generated large amounts of carrion available for scavenging, a fact that is thought to have facilitated the earliest (attempts of) dispersals of hominins into Eurasia during the Earlier Pleistocene (*ibid.*). Thus, on the basis of the documented co-presence of *M. whitei* with hominin remains (*e.g.* Dmanisi), as well as the location of Mygdonia near the Bosphorus Strait, *i.e.* at the presumed dispersal route of both

early hominins and *M. whitei* (and at a similar latitude with Dmanisi), the researchers note that it would not be surprising to find in the near future hominin remains in one of the localities of the Mygdonia basin (*ibid.*). Such remains are yet to be found, and the artefacts from Doumbia may indeed be pointing to that direction.

4.4 IONIAN ISLANDS

From a geotectonic perspective, the Ionian Islands belong to the Ionian isopic zone, which mainly covers the part of Epirus west of the Pindos Front (see below 6.3), and to the Pre-Apulian zone, which is part of the Apulian platform of Italy (Higgins and Higgins 1996). Similarly to this geotectonic division, the islands on one hand share common geological, geomorphological and climatic characteristics with Western Greece, and on the other hand present cultural features that connect them with both the Greek coastal areas to the east and those of the Italian and Dalmatian coasts to the west. A mountainous landscape predominates mainly in the western parts, whilst a more subdued relief in the eastern parts emphasizes the sense of continuity with the adjacent mainland: Kerkira is practically the geomorphological continuation of Epirus; Lefkada and Ithaki relate to Acarnania, whereas Kephallonia and Zakynthos (mostly their south-eastern areas) are associated with north-western Peloponnesus (Kourtesi-Philippakis 1999). Thus, as it is also the case with western Greece, limestone predominates in the geological substratum, karstic landforms are abundant and the climate is meso-Mediterranean, presenting the highest rainfall values in Greece. Furthermore, the islands are situated between the westernmost part of the Hellenic subduction zone and the continental collision zone: a seismotectonically active area that is subjected to rapid and intense crustal deformation, which is in turn expressed in the islands (except Kerkira) experiencing the highest seismic activity in Europe (Lagios *et al.* 2007; see also 6.3 and references therein).

Already from the 1960's, it has been demonstrated that humans were present on the Ionian Islands during the Middle and Upper Palaeolithic periods (Sordinas 1969, 1970; Kavvadias 1984; Kourtesi-Philippakis 1999; Dousougli 1999). The bulk of the

evidence comes in the form of lithic surface finds, recovered from open-air sites in various depositional settings, such as coastal plains, karst plateaus, alluvial fans and marine terraces. Noteworthy is the discovery of artefacts associated with *terra rossa* deposits that fill karst depressions, much like the ones which dot the landscape of neighbouring Epirus (Sordinas 1970; Dousougli 1999; see also 4.5 below). Some of the artefacts attributed to the Middle Palaeolithic (most notably from Kerkyra, Kephallonia and Zakynthos) have been considered to display affinities with the Pontinian industries of Italy, or with material from the Balkans, and also with industries discovered in Elis (north-western Peloponnesus) or Preveza (south-west Epirus) (Kourtesi-Philippakis 1999; Runnels and van Andel 2003).

4.4.1 Nea Skala, Kephallonia

In 1974, A. Cubuk discovered flint artefacts at a site located in the south-eastern extremity of Kephallonia, ca. 1.5 km north of Nea Skala. The artefacts (Fig. 4.5) were collected from the surface of two marine terrace-remnants that are cut into a limestone hill at 85 and 75 m a.s.l. respectively, whilst a third, lower terrace occurs at 20 m a.s.l. and yielded artefacts attributed to the Middle Palaeolithic (Cubuk 1976). Eighteen of the forty-one specimens collected from the highest terrace show clear signs of rolling, whilst all of those from the lower one (N= 44) were recovered in a fresh condition (ibid). In both assemblages, flakes and chopping-tools predominate, followed by choppers made on flakes, and cores (ibid). In both terrace-remnants, the deposits are described as consisting of loose and well-rolled limestone and flint gravels (ibid: 176).

The fact that rolled artefacts occur only in the higher terrace is taken by Cubuk as an indication that the two terraces were formed in different phases; nevertheless, in lack of any other chronostratigraphic indications (e.g. from mollusc or other faunal remains), the researcher notes that it is impossible to place the terraces in a chronological sequence according to their elevations alone (Cubuk 1976, 177). The overall compressional regime and the associated uplift affecting the region (see also 6.3 below), as well as the presence of the Ionian thrust fault a few kilometers to the north-west of the area, makes it reasonable to at-

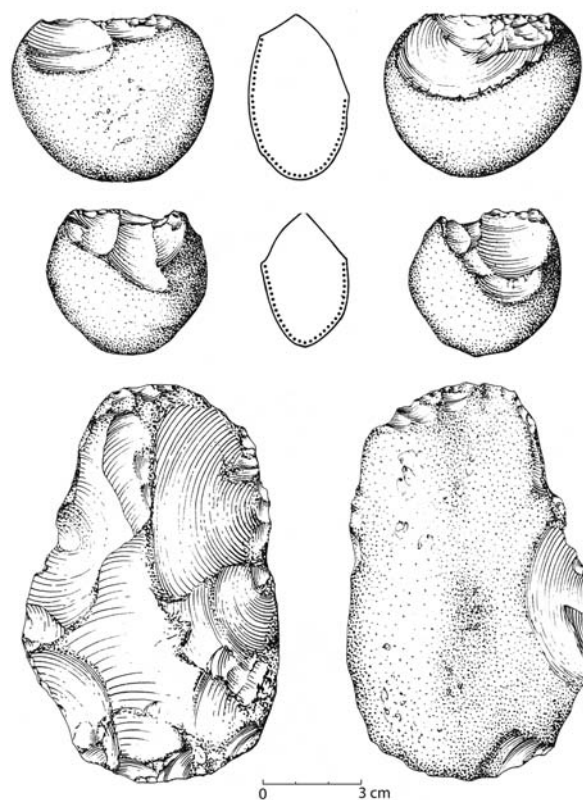


Fig. 4.5 Artefacts from Nea Skala, higher terrace. Redrawn after Cubuk 1976: fig. 4

tribute the formation of these terraces to eustatic sea-level variations resulting in episodes of marine transgressions during sea-level highstands, which were later fossilized and preserved due to uplift. Yet, even if a long-term, largely continuous uplift could securely be assumed, it would not be feasible to attempt any correlation with (dated) raised Quaternary marine terraces preserved elsewhere in Greece, on the basis of their altitudinal occurrence alone and without further study of other morphotectonic indications. For example, in the marine terrace staircase preserved in the southern side of the Corinth Gulf, a terrace correlated with MIS 5 occurs in one locality at 35 m and some 40 kilometers away it is found between 150-169 m asl, due to the effects of differential uplift rates (Keracaudren and Sorel 1987, 101).

Cubuk attempted some gross comparisons of the artefacts with similar material ('pebble tools') from Latakia (Syria) and from the eastern coasts of Italy (Cu-

buk 1976, 177). On the basis of the morphology of the artefacts and the altitude of the terraces, he suggested that the latter are likely to be correlative to the ‘Milazzo terraces’ (ibid, 176). As stated previously, comparisons based on altitudinal similarities should be deemed inadequate for a chronological estimation; in any case, it is now known that the marine terraces at Milazzo (north-eastern Sicily) are to be attributed to the sea-level high-stand of MIS 5.5 (e.g. see Antonioli *et al.* 2006). All things considered, if the terraces at Nea Skala remain undated, that is even more true for the artefacts that were found lying upon them: their attribution to the Lower Palaeolithic on the basis of the terrace-heights and the high frequency of pebble tools should be regarded tenuous until their context is better studied and dated.

4.4.2 Korissia, Kerkyra

A chopper was found by two geologists, stratified in clay deposits near the lagoon of Korissia, in south-west Kerkyra. The stratigraphy has been described as following (Kourtessi-Philippakis 1999, 283): Middle Pliocene marls and sandstone are overlain by layers of algae-bearing calcarenites, including gastropods and bivalves that indicate a Quaternary age. Above the latter, there are sandy layers with intercalations of lignite, overlain by a five-meters-thick deposit of grey clays containing *Cardium* and *Cerithium*; the chopper was recovered from these clays. Palaeomagnetic measurements of the clays yielded a normal magnetic polarity, which the researchers attributed to the Brunhes epoch (ibid). As this is the only age-estimate obtained for the deposits, the artifact could date anywhere within the period of the Brunhes: it is therefore not possible at yet to securely attribute the specimen to the Lower Palaeolithic on chronostratigraphic grounds. If the specimen was lying in a primary position, its place in the local stratigraphic sequence indicates a Middle Pleistocene age (cf. Darlas *et al.* 2007). However, a recent revisit at the chopper’s findspot raised some doubts about the *in situ* character of the implement (Darlas *et al.* 2007). Erosional products of loose material, including lithic artefacts, derive from a vertical cliff that is formed above the coastline, and these end up to the level from which the chopper was retrieved (ibid, 29); as the chopper-bearing layer displays numerous cracks due to the swelling of the clays (P. Karkanias, pers.

comm. 2010), it is probable that the artifact derives from younger, overlying strata and was later engulfed in the clays (Darlas *et al.* 2007, 29).

4.5 EPIRUS

4.5.1 Introduction

The rockshelter of Asprochaliko, the cave of Kastritsa and the open-air site of Kokkinopilos are the principal sites that provided for the first time a relatively solid framework for a stratified Palaeolithic sequence in Greece (Bailey *et al.* 1992; see App. I: 34 for locations of sites). Since its discovery by Eric Higgs in the 1960’s, Kokkinopilos has yielded more than 10,000 lithic specimens made on a local variety of bluish-grey, relatively fine-grained nodular flint, which permitted the manufacturing of artefacts that are “in quantity, quality of workmanship and preservation unique” (Higgs 1963, 2). Apart from a small Upper Palaeolithic component, the bulk of the Kokkinopilos material was initially described as ‘Levallois-Mousterian’ with bifacial leafpoints and a preponderance of racloirs (Higgs and Mellars in Dakaris *et al.* 1964); later, it was made clear that the collected pieces should not be considered as representing one single Mousterian industry, but rather a mixture of artefacts from different localities within the site, reflecting a high degree of technological and typological variability, to the point that “Kokkinopilos is better viewed as a sort of two-dimensional Combe-Grenal” (Papakonstantinou and Vassilopoulou 1997, 466; Papagianni 2000). Mellars included a few ‘Clactonian’ and chopper-like cores among the unclassified pieces (Dakaris *et al.* 1964, 235) and Higgs mentioned already in 1963 a broken tip from a handaxe, but in neither case was any remark expressed for a possible presence of material earlier than the Mousterian. Such a claim was first put forth in 1993 by Runnels and van Andel in their publication of their work at Kokkinopilos and the discovery of a ‘Micoquian’ handaxe. However, in contrast to earlier studies of lithic assemblages from Kokkinopilos and other redbed sites of Epirus, in which typological assessments predominated (Papagianni 2000), the attribution of this handaxe to the Lower Palaeolithic was in this case based on stratigraphic grounds (Runnels and van Andel 1993a).

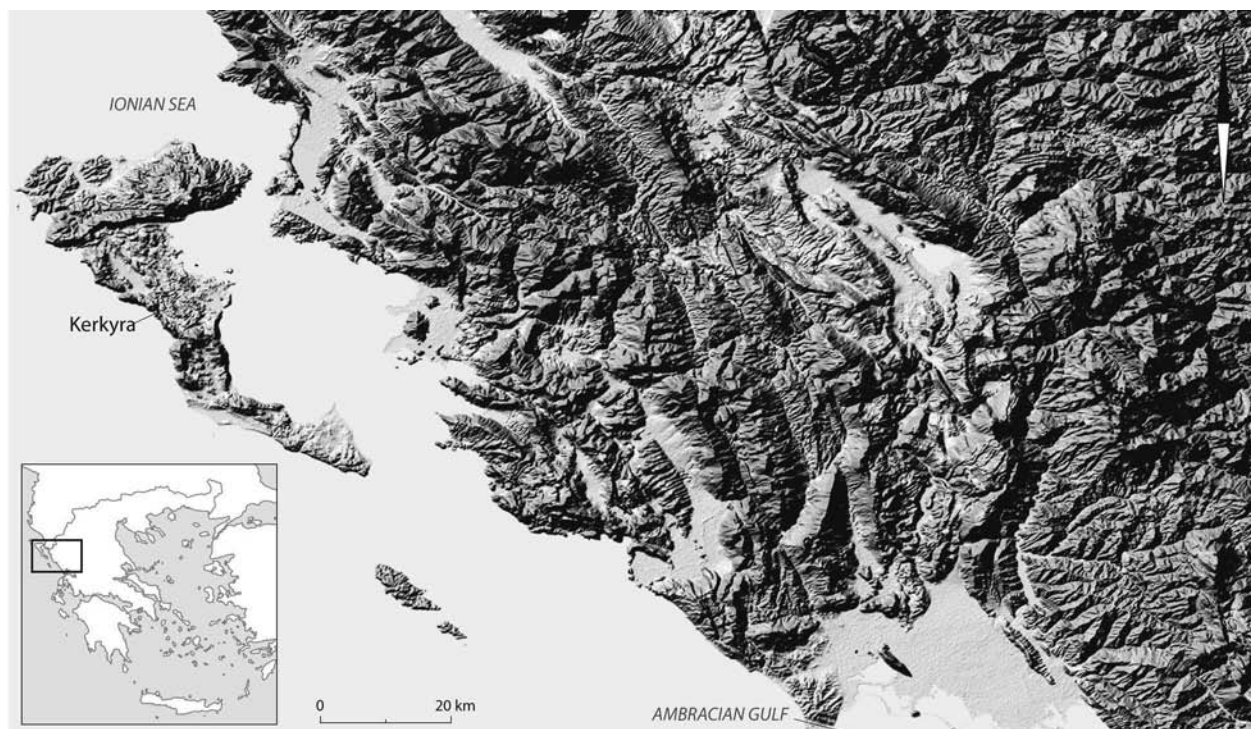


Fig. 4.6 Relief map of Epirus, based on data from Shuttle Radar Topography Mission (SRTM), version 2, available at <http://www2.jpl.nasa.gov/srtm>

Epirus not only possesses the largest Palaeolithic database but has also yielded the largest sample of artefacts with a bifacial technology, which is so far rare in the eastern part of Greece and overall scanty in the Balkan Peninsula (*cf.* Runnels 2003b). Any alleged affinities of these few handaxes to an ‘Acheulean technocomplex’ seem probable, but without a solid chronostratigraphic framework such inferences remain intuitive and highly tenuous. As with the case of Alonaki examined below, until further evidence comes to light, the possibility that such ‘primitive-looking’ material is part of an early Mousterian continuum, remains open. Interpretations based on typotechnological criteria are further hampered by the fact that sites like Kokkinopilos undoubtedly represent a significant focus of occupation and/or exploitation during repeated visits of human groups over time-periods that range from the (Lower?) Palaeolithic up to the Roman times; therefore, a palimpsest character of the record is expectable, and the only means to unravel the emerging complexity is by investigating the existing as well as potential inter- and intra-site stratigraphic associations. Kokkinopilos

has suffered much from erosion, but being a relatively large open-air site, it still affords the potential of separating distinct ‘occupation events’ in both a vertical and a horizontal axis. Obviously, this requires that the stratigraphic integrity of the site is *not* overall questionable. It is mainly on this issue that the results from the recent research carried out by the author are hoped to shed some light.

4.5.2 Geology, geomorphology and geoarchaeology of Epirus

In contrast to the smoothly undulating, riverine landscape of Thessaly, Epirus is characterized by a complex topography and a rugged relief (Fig. 4.6). This is a land of steep mountains, many streams but few rivers, narrow valleys, coastal plains and lagoons, and it presents the highest precipitation values in Greece. In the northern and eastern parts, the mountain range of Pindus, the ‘backbone’ of mainland Greece, defines the region’s boundaries and exemplifies the high-relief face of Epirus, where peaks up to 2600 m alternate with deeply incised river gorges. To

the west of the Pindus Front Range, the western and southern parts of the region are bounded by the Ionian Sea and the Ambracian Gulf. Here lies a karst landscape of carbonate platforms and flysch basins, separated by high and narrow limestone ridges, whilst the terrain becomes more subdued towards the coastal zone in the west and the south, especially in areas where river deltas are formed (*cf.* App. I: 35). This topographically diverse landscape with a plethora of alternating micro-environments served as a refugium area for trees, protecting them from the effects of Quaternary climate changes, and it is still considered a 'hot spot' of endemism for plants and animals (Tzedakis *et al.* 2002b).

Overall, the plateau-ridge system with Late Neogene to Pleistocene intramontane basins can be understood in terms of an intense tectonic history (see section 6.3), particularly since Epirus is situated at the point where three tectonic plates meet, making it one of the most active regions in Eurasia (Bailey *et al.* 1993). As a result of plate convergence between the Apulian plate and the Aegean plate, north-western Greece has been subjected to east-west shortening, which is manifested by a predominantly compressional regime, especially to the west of the Pindus thrust belt zone (Doutsos *et al.* 1987); notably, compression still continues today (Higgins and Higgins 1996). Regional uplift associated with compression contributed significantly to the high topographic relief, and, whilst most researchers emphasize thrusting and folding, producing both anticlines and synclines, others stress also the influence of strike-slip faulting and the role of Plio-Pleistocene extensional tectonics (King *et al.* 1993; Doutsos and Kokkalas 2001; van Hinsbergen *et al.* 2006). Whereas most of mainland Epirus has been undergoing uplift at least since the Pliocene, there is evidence to suggest that some areas, such as the Ambracian Gulf, the lower Acheron valley, the valley of river Thyamis and much of the coastal zone, are either subsiding or static, thereby preserving thick deposits of Quaternary sediments (King and Bailey 1985; Besonen *et al.* 2003, 208).

Bailey and coworkers argued that widespread deformation associated with intense uplift (and subsidence) would have had a substantial impact on Palaeolithic landscapes of Epirus, affecting resource availability and use, but Runnels and van Andel

(2003) challenged the high values for uplift and subsidence rates proposed by Bailey and his team (King and Bailey 1985; Bailey *et al.* 1993). Nonetheless, the latter researchers convincingly show how tectonic activity may have had aspects that were advantageous for hunter-gatherer economy: geological structures created by normal faulting or compressional folding can serve as sedimentary traps, which are able to maintain stable environmental conditions for plant and animal communities by acquiring a degree of insensitivity to changes of climate and land use (Bailey *et al.* 1993). For example, areas upstream from an uplift zone can be subject to ponding by the damming effects of tectonic vertical motion; ponding may in turn be preserved throughout the course of climatic changes and attain the character of a persistent and/or recurrent feature in the landscape, thereby attracting animals and humans. This was postulated to explain persistence of human presence in the cave of Asprochaliko and the open-air site of Kokkinopilos (King and Bailey 1985, 280). In addition, tectonic structures and their topographic expressions, such as limestone ridges produced by faults, can form topographic closures and barriers dictating animal movements; the latter can then be predicted and monitored by humans, and this is thought to be reflected in the patterned relationship of Palaeolithic rockshelters (Asprochaliko, Klithi, Kastritsa) with regional features of points of entry/exit for animal herds (Bailey *et al.* 1993, 304). Although not so much in connection to tectonics, the role of a closed topography (providing also diverse resources over short distances) was noted by Higgs' team as well, with regard to the location of Kokkinopilos (Dakaris *et al.* 1964, 213).

Runnels and van Andel (2003) recognize the importance of tectonism in the configuration of the Epirote landscape as regards both preservation factors in depositional settings and the creation of landscape attributes that would be attractive to early humans, but their contribution to the discussion comes with their investigation of the role of karst features. Limestone and flysch are the dominant substrate types of the region and, whereas limestone plateaus are relatively undisturbed today, the flysch basins are tectonically very active (Bailey *et al.* 1993). Flysch is very susceptible to erosion and prone to form heavily gullied badlands, and this may be seen as explaining the gen-

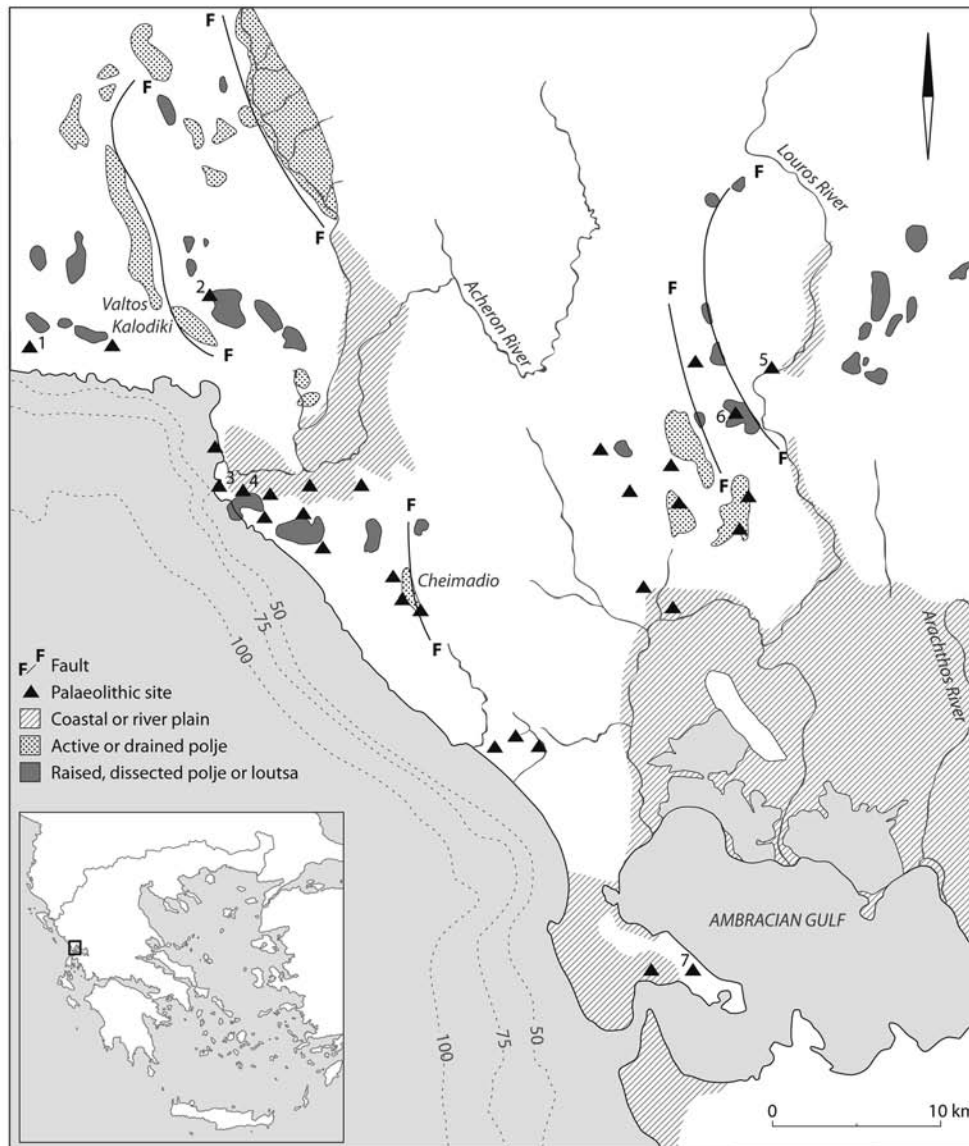


Fig. 4.7 Map of south-western Epirus showing the association of Palaeolithic sites with poljes and 'loutsas'. Numbered sites (mentioned in text): 1) Ayia 2) Morphi 3) Ormos Odysseos 4) Alonaki 5) Asprochaliko 6) Kokkinopilos 7) Ayios Thomas. Modified after Runnels and van Andel 2003: fig. 3.8 and van Andel and Runnels 2005: fig. 7

eral absence of Palaeolithic finds from the flysch basins (ibid; but see Efstratiou *et al.* 2006 for the presence of Middle Palaeolithic sites in the flysch landscapes of the Grevena uplands in Macedonia). On the other hand, land surfaces shaped by the dissolution of limestone, namely karst landforms, are not deformed by horizontal concentrated flow of surface water; rather, the water here drains mostly downwards through cracks and fissures into subterranean conduits. Thus, it is mainly the action of water and

tectonic activity, which form those conspicuous landscape features of Epirus, the karst depressions, with which most Palaeolithic sites of Epirus are associated (Fig. 4.7). *Poljes* are enclosed, often fault-bounded, flat-floored basins surrounded by hills with rather steep slopes; they are drained by sinkholes in the floor rather than by rivers or streams, and because drainage is inadequate, they are usually flooded in winter but can be dry in the summer, namely hosting either permanent or seasonal lakes. In contrast to the



Fig. 4.8 Oblique aerial view showing the wider area of Kokkinopilos. Lines denote major faults. The river Louros runs parallel to the road visible as a white line to the right of the picture

tectonic origin of the poljes, *loutsas* (singular: *loutsa*) are small and shallow solution basins fed by winter and spring runoff.

4.5.3 Previous research and interpretations¹⁵

With a few exceptions, most of the open-air Palaeolithic sites in north-west Greece are associated with red sediments, the so-called ‘redbeds’ of Epirus, and E. Higgs was one of the first to recognize this association (Dakaris *et al.* 1964; Higgs and Vita-Finzi 1966). Since the 1960’s, there has been a long-lasting debate over the chronological and depositional relationship between artefacts and sediments at all red-bed sites of Epirus. The key points of this discussion refer to the origin of the red sediments, their depositional context and the processes involved in their accumulation, as well as the time-span represented by the deposits. Obviously, possible answers to those

geological questions will dictate the resolution of the main archaeological inquiries, of which the most important regards the chronological relationship between the lithic artefacts and the red sediments, and if there is any potential for recovering artefacts from geologically undisturbed contexts; or, alternatively, whether erosion and redeposition have resulted in the mixing of the deposits (and hence of artefacts as well) in all the sites (*cf.* Papagianni 2000). Because Kokkinopilos has acquired a central role in this discussion, and interpretations based on geoarchaeological work at this site have been extended to all other open-air ‘redbed sites’ in Epirus (*ibid.* 29), the models developed to answer the above questions will be examined in conjunction with the investigations at Kokkinopilos.

Kokkinopilos is situated at *ca.* 120-150 m asl in a valley to the west of the Louros river, from which it is separated by a limestone ridge that runs parallel to a fault (Fig. 4.8). The deposits of the site consist of *ca.* 30-40 m-thick consolidated clayey silts and silty clays of uniform lithology, they cover about 1 km² and are currently being rapidly eroded in an extensive network of gullies, which altogether make up

15. Research in Epirus is extensively reviewed by Papagianni (2000) and Runnels and van Andel (2003). The limited space available here allows only for a synoptic consideration of this discussion.

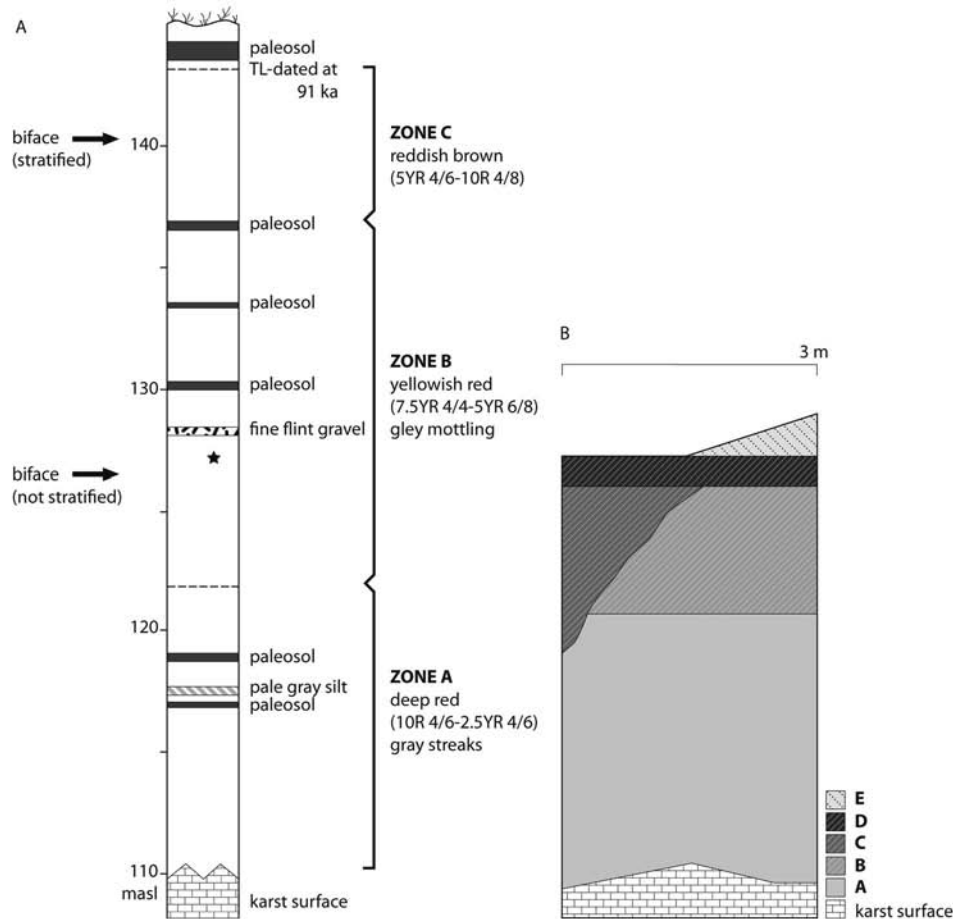


Fig. 4.9 Schematic cross sections of Kokkinopilos: A) modified after Runnels and van Andel 2003: fig. 3.17; this is the zonation adopted in this study; the stratigraphic positions of the two bifaces that I discovered (see text) are indicated, whilst the asterisk marks the position of the handaxe found by Runnels and van Andel (1993a). B) cross section after Bailey *et al.* 1992: fig. 4

the appearance of a badland landscape (App. I: 1, 2). As discussed below, the site is part of a fault-bounded depression, a polje which, in its later stage of evolution, was uplifted and in turn dissected by headward stream incision. The instability of the land surface is reflected in the scarcity of vegetation, which is restricted to only a few thickets where soil has been retained, whilst the degree of erosion can be apprehended in the undercutting and exposure of the root systems (Harris and Vita-Finzi 1968; App. I: 3). In Roman times, tunnels were dug through the deposits to conduct water from the Louros river to the city of Nikopolis, and the towers of the ventilation shafts of the aqueduct are still partly in place. Locally, the bases of the shafts lie ten or more meters above the floors of the gullies, and this has been con-

sidered as an indication that the dramatic erosion seen today is of post-Roman age (Dakaris *et al.* 1964, 213). However, at another location in the western part, a tunnel emerges at the foot of a gully, suggesting that erosion may have been initiated before Roman times (Harris and Vita-Finzi 1968, 539). By studying the profile of the Louros river, King and Bailey (1985) suggested that the transition from deposition to downcutting in this part of the river's course must have occurred after Upper Palaeolithic times and before the Bronze Age. Artefacts most probably dating to the Bronze Age are being found on and occasionally inside the 'topsoil' (see below), indicating that this was a relatively intact surface up to that period. Even if erosion was affecting the site already during Palaeolithic times, all researchers

agree that the dramatic erosion creating this badland-landscape should be post-Roman, and probably was accelerated even much later, namely after the 1950's, as suggested by different lines of evidence (Harris and Vita-Finzi 1968, 541; Bailey *et al.* 1992, 143).

The original division of the stratigraphy into three main zones (Fig. 4.9), A, B and C from bottom to top is mainly based on colour differences (Dakaris *et al.* 1964). It has been retained in all subsequent studies and it is described in detail by Tippet (ibid, 221-225) and Runnels and van Andel (1993a; 2003). Zone A rests on the limestone bedrock and is uniformly deep red (2.5YR 4/6) with few grey veins and streaks; no artefacts have been found in this zone. Zone B is more yellowish red (7.5YR 4/4 to 5YR 6/8), displaying abundant grey veins and mottled bands, whilst zone C has a reddish-brown colour (5YR 4/6 to 10R 4/8) and is marked by grey stripes similar to those of zone B, albeit usually thinner (App. I: 4). A fourth 'layer D' of dark red colour was identified overlying zone C but it was left unnamed by Tippet (and largely ignored); later, Bailey *et al.* (1992) described it as a *soil* locally overlying either zone B or zone C (but see below). A fifth layer, reported by Bailey *et al.* as a slopewash deposit 'E' (ibid; Fig. 4.9), is not mentioned by Runnels and van Andel (1993a; 2003), and I was not able to confirm its existence. Black manganiferous bands marking the boundaries between zones A – B, and B – C, are thought to indicate interruptions of the sedimentation by erosional periods of unknown duration, but as Tippet notes, "despite these breaks, and the differences of color, [...] this is essentially a single deposit" (Dakaris *et al.* 1964, 225).

Originally, Higgs and colleagues (in Dakaris *et al.* 1964) suggested an aeolian origin for the sediments, the deposition of which was thought to have occurred between two cold spells of the 'Last Glaciation'. Later on, they postulated an alluvial origin, reporting that "water-laid gravels were found intercalated with the 'red earth' deposits", and explaining the apparent lack of bedding by invoking the effects of physical/chemical post-depositional processes that have erased the traces of the original stratification (Higgs and Vita-Finzi 1966, 3-4). In this new appraisal, part of the sequence was considered to have been formed "before the Mousterian occupation", whilst "the

Upper Palaeolithic occupation came towards the end of the Red Bed deposition" (ibid, 5-6).

Most of the surface finds were collected from the erosion gullies and were described as heavily patinated -but in sharp condition- 'Mousterian pieces', whilst an industry of unpatinated, smaller artefacts was found "*in situ* in a gully side" and was ascribed to the Upper Palaeolithic; a few Bronze Age artefacts were (and are still being) found always on the modern surface (Higgs 1963; Dakaris *et al.* 1964, 215). Already in his first, preliminary report, Higgs notes the presence of 'chipping floors' that "lie in thin horizons some four inches in thickness" (1963, 2). Such chipping floors were identified in thirteen locations, where "the artefacts could be seen *in situ* in the gully sides" (Dakaris *et al.* 1964, 215). Test trenches were opened in two of these locations (Sites α and β) but they were never put on a map and there is some confusion with regard to their precise positions and the number of the associated lithic material (due to curation problems; see Papagianni 2000, 70-77). At Site β , the excavation cut through deposits of zone B and into zone A, while most of the recovered artefacts (collectively described as Mousterian) were found at the base of zone B, immediately above the junction with zone A; Higgs reports that "some 800 artefacts were found *in situ*" in this trench, all from zone B (Dakaris *et al.* 1964, 215). The trench of Site α was cut in the place where the 'Upper Palaeolithic material' was identified in 1962 *in situ* in a gully side. A concentration of *ca.* 500 lithic tools and debris was found at 3.5 m below the surface at the base of zone C, where the artefacts "appeared to follow the line of an old erosion gully cut into zone B and subsequently filled by the zone C deposit" (ibid, 217). In the next publication, Higgs noted that this is "either a chipping floor *in situ* in an ancient gully or (as there has been no sorting of the flints) one which has not traveled very far" (Higgs and Vita-Finzi 1966, 5). Overall, the results from the two excavated sites led Higgs to conclude that

"after a basal breccia a red clay [*i.e.* zone A] had been deposited. Deposition had ceased and a minor erosion had taken place. After this erosion a very similar yellowish-red clay had been deposited and at the beginning of its deposition there had occurred a Middle Palaeolithic occupa-

tion. This deposition had continued until the layer was 12-20 feet [*i.e.* 3.7-6.1 m] in depth. At this point a cessation of deposition had occurred and a blade industry had occupied the eroding surface. Subsequently Zone C, a reddish-brown clay had been laid down to a depth of some 11 feet [*i.e.* 3.4 m] above the blade industry which included, at 2 feet from the surface, a band of angular stones” (Dakaris *et al.* 1964, 217-219).

After the death of E. Higgs, research resumed in Epirus with another team from Cambridge under the direction of G. Bailey. King and Bailey (1985) accepted the model for an alluvial origin of the sediments, but they suggested that the Kokkinopilos redbeds were deposited by the Louros river itself, which, in this scenario, would be flowing at a higher level than today. As the redbeds occur today at *ca.* 50-100 m above the river level, considering them as part of the valley fill would imply that the cave of Asprochaliko (which is now 20 m above the river) was buried by the same fill at a time when it was inhabited. To explain this contradiction, King and Bailey (*ibid.*) proposed that the high level of the deposits is a result of local tectonic uplift. Papagianni (2000, 30) notes that this scenario was later criticized by the same team (D. Sturdy cited as ‘pers. comm.’ in Papagianni 2000), because of the high values of localized uplift that would have been required to lift Kokkinopilos 50-60 m higher than Asprochaliko within the last 40,000 years. Later, Bailey and colleagues abandoned the ‘alluvial hypothesis’, suggesting colluvial deposition of the redbeds, which were viewed now as “chemical or biochemical byproducts of limestone degradation” deposited “in a shallow, seasonal lake or marsh”, or “by heavy seasonal rainstorms as the shallow distal edge of a fan” (Bailey *et al.* 1992, 142). Yet, the most important aspect of this latter re-assessment regarded the *dating* of the redbed formation: rather than the time-frame of the Last Glacial invoked earlier, Bailey *et al.* advocated that the sediments of Kokkinopilos “are at least of Middle Pleistocene date and may be very much older” (*ibid.*, 140). They regarded zone B as pedogenically altered zone A, and the occasional small lenses of fine gravel in zone C as “gully fill deposits representing reworking of the main clays by seasonal streams” (*ibid.*). Additionally, Bailey and co-workers argued that both *Site α* and *β* were excavated in disturbed

deposits, thereby dismissing the claims for artefacts being found *in situ*. In fact, Bailey *et al.* explicitly concluded that “none of the artefacts recovered from Kokkinopilos can be demonstrated to be geologically *in situ*”, that “the artefacts form a mixture of materials from many different periods” and “do not date the accumulation of the main body of red clays at all, but postdate them by an unknown interval” (*ibid.*, 142). Importantly, they also stated that “essentially the same point could be made about the other open-air sites in Epirus” (*ibid.*).

Notwithstanding the importance of these early contributions, it was with the work of Runnels and van Andel in the frames of the Nikopolis Survey Project that a thorough interpretative model was put forth to explain all major geo-archaeological questions surrounding the ‘redbed sites’ of Epirus. Their analyses and argumentation have been described in great detail in a series of publications (Runnels and van Andel 1993a; van Andel 1998; Runnels *et al.* 1999; Runnels and van Andel 2003; van Andel and Runnels 2005), the main points of which are reviewed below.

Runnels and van Andel (2003; van Andel 1998) distinguish three main types of red deposits: (1) primary *terra rossa*, which is the insoluble weathering residue produced (*in situ*) by the dissolution of limestone¹⁶ (see also Yassoglou *et al.* 1997; Yaalon 1997; Durn 2003); due to Quaternary erosion, *terra rossa* is rarely preserved in primary locations, usually to be found in small, localized karst depressions; (2) redeposited *terra rossa*, namely *terra rossa* washed down from primary locations into karst basinal features, such as poljes; (3) colluvial red beds, which, unlike the other two types, include coarse-grained material transported by mass wasting processes and/or running water (App. I: 5). Another important and yet tricky distinction is between red sediments and paleosols, since the latter are often as red as *terra rossa*. Building on their previous research elsewhere in Greece (*e.g.* Pope and van Andel 1984; Runnels and van Andel 1993b) Runnels and van Andel (2003: Table 3.11) used paleosol stratigraphy,

16. Primary *terra rossa* is itself a paleosol (van Andel 1998, 362).

aided by TL and IRSL dating (see below), in order to compile a chronostratigraphic scheme for archaeological sites, sediments and paleosols in southern Epirus.

The latter researchers showed that the red sediments of Kokkinopilos and most of the other ‘redbed sites’ with Palaeolithic finds are in fact *terra rossa redeposited* in the depositional environment of karst depressions, namely that of poljes and loutses. Being fine-grained, as the mantle of *terra rossa* slowly thickens in primary locations, infiltration is reduced, allowing surface runoff to transfer it into the depressions. Uplift accelerates weathering and slope wash, resulting in the filling of poljes and loutses with secondary (redeposited) *terra rossa*; continued uplift raises the poljes and forces streams to cut back upstream, capturing the poljes, dissecting their surfaces and draining any water bodies (App. I: 36). Thus, nearly all of *terra rossa* in Epirus is to be found in secondary locations, and whilst some of it may be in colluvial deposits and alluvial fans, most of it occurs in poljes or loutses. Because the latter host seasonal or permanent lakes, water reduces the dark red colour of *terra rossa* into paler hues, whilst under dry conditions (e.g. due to uplift or during drought intervals) the discolouration process can be reversed, re-reddening the sediments (van Andel 1998, 377). Inadequate understanding of the role of karstic depressions as the main depositional environments of redeposited *terra rossa*, and failure to recognize the discolourations of the latter by varying groundwater levels in poljes/loutses, led previous researchers to erroneous and often contrasting interpretations of the redbed sites.

New and detailed grain size analyses carried out by Runnells and van Andel demonstrated that *terra rossa*, primary or redeposited, exhibits two size frequency modes: clay (50 to >90%), produced by the dissolution of limestone, and silt (5-30%), consisting almost entirely of quartz (Runnells and van Andel 2003, 66-67). In accordance with the suggestion for a windblown origin of the silt mode, first noted by Tippet and Hey (Dakaris *et al.* 1964), Runnells and van Andel (*ibid.*, 69) confirmed that the silt component has an aeolian origin, probably from the Sahara (Yaalon 1997, 2009). Complete bleaching during aerial transport renders the material suitable for TL and

IRSL dating, allowing for a luminescence dating program for western Epirus (*ibid.*, 91; Zhou *et al.* 2000).

In 1991, Runnells and van Andel (1993a) discovered a patinated, Micoquian-type handaxe that was stratified *in situ* within deposits of zone B. The artefact was found in a horizontal position, lacking traces of abrasive damage or weathering (*ibid.*). Large and heavily patinated artefacts were seen at almost the same or slightly higher stratigraphic levels in other localities to the south and south-west of the handaxe-findspot, whilst large flake tools (including denticulates and notches) were observed “eroding from the sediments in the northwest part of the deposit and perhaps similar to the ‘chipping floors’ described by Higgs in the northeast part of the site some 300 m away”; due to permit issues those artefacts were not collected (Runnells and van Andel 2003, 99). Importantly, it was noted that the artefacts were separated by clay matrix from each other and there was no size sorting or any mixing with unpatinated specimens, as it would be expected if they were included in the fill of an erosional gully (Runnells and van Andel 1993a, 192). Runnells and van Andel (1993a, 194) recognized that the deposit overlying zone C (Fig. 4.9) is in fact the Bt horizon of a paleosol –a recognition that was not included in Tippet’s account of the stratigraphy (in Dakaris *et al.* 1964, 222) and was largely ignored by Bailey *et al.* (1992). Heavily patinated artefacts of Middle Palaeolithic technology were observed locally, occurring *in situ* within the paleosol, which is preserved mainly along the edges of the polje, capping the entire stratigraphy¹⁷ (Runnells and van Andel 1993a). This paleosol was TL-dated at 91 ka (Zhou *et al.* 2000). The latter dating, together with extrapolated sedimentation rates (corrected by the variations of the clay/silt ratio) allowed the researchers to estimate the age of the handaxe-bearing layer at *ca.* 150-250 ka (*ibid.*; Runnells *et al.* 1999; Runnells and van Andel 2003).

17. A modern ‘topsoil’ overlies this paleosol. Unpatinated artefacts can be found on the surface of the topsoil (e.g. App. I: 19), whilst the paleosol yielded only patinated specimens; this suggests that the latter were not incorporated recently into the paleosol (Runnells and van Andel 1993, 194).

Another paleosol was identified at the junction of zones B and C, whilst two moderately mature¹⁸ paleosols, reported to be “associated with thin, discontinuous gravel lenses rich in small flint fragments, many of them [being] Palaeolithic artifacts”, occur in zone B, and two more are present in zone A (ibid, 70, 73; Fig. 4.9). These paleosols, together with the black manganiferous bands and/or desiccation zones at the boundaries of zones A-B and B-C, indicate interruptions of the sedimentation and intervals when dry surfaces were exposed. Alternatively, the diffuse gray mottled bands and gley zones designate fluctuations in groundwater level during and after deposition, whilst sub-vertical grey stripes probably denote the presence of water circulating in root channels; particularly in zone B, subhorizontal laminations suggest that deposition took place mainly under water. Overall, the fine-scale stratification, observed also in the localities where artefact scatters were identified, points to a depositional environment of very low-energy conditions, “far too low to entrain even the smallest flint debitage” (Runnels and van Andel 2003, 76). Similar conclusions were derived from the study of other poljes and loutsas: notwithstanding the sporadic occurrences of bands with fine to medium gravels, probably indicating thin debris flows or the action of small ephemeral streams, as in the case of the polje of Ayia, the fine bedding strongly suggests “slow, non-erosive, seasonally-interrupted depositions” (van Andel and Runnels 2005, 377).

In sum, Runnels and van Andel suggested (and largely proved) that the fill of the redbed sites refers to *terra rossa* (consisting of clay from the limestone dissolution, washed down from the flanks of the basins, and silt of windblown origin), which has been redeposited in runoff-collecting karst depressions. Such enclosed, flat-floored basins formed shallow, seasonal or perennial lakes and marshes, which would entail low-energy transporting agents and depositional environments. In these settings, artefacts resting on or within paleosols point to human pre-

sence during brief dry periods, whilst lithic scatters *not* associated with paleosols indicate exploitation of the lacustrine resources while the lakes were active.

4.5.4 Revisiting Kokkinopilos: fieldwork results

Essentially, the main point of contrast between the model proposed by Bailey and colleagues (1992) and that of Runnels and van Andel (1993a; 2003) regards the chronological relationship between the deposition of the red sediments and the discarding of the flint artefacts. In effect, the former researchers argued that the artefacts were discarded long after deposition had ceased and that all of the material is in secondary locations, buried by reworked sediments; whilst the latter scholars advocated human presence at Kokkinopilos while either deposition or soil formation was still ongoing, thereby suggesting the possibility of finding intact deposits with stratified artefacts, for which an age estimate can be assigned by dating the associated deposits.

In 2007 and 2008, I visited the site of Kokkinopilos with the aim of evaluating the aforementioned contrasting interpretations on the integrity of the site and the prospects of finding archaeological material that can be demonstrated to be geologically *in situ*. Kokkinopilos has been designated a National Monument by the Greek Ministry of Culture and it should be noted here that the permission I was granted did not allow the excavation of test trenches nor the collection of material¹⁹. Detailed grain-size analyses and numerous colour readings according to Munsell Hue had already been carried out by Tippet (Dakaris *et al.* 1964) and Runnels and van Andel (1993, 2003), whilst the lithic material had been studied by P. Melars (in Dakaris *et al.* 1964), Papakonstantinou and Vassilopoulou (1997) and D. Papagianni (2000). Consequently, the revisit was restricted to macroscopic observations at the site (including sampling for dating purposes after a new permission was issued, see below), as well as a brief inspection of a small sample of relevant lithic material in the museum of Ioannina.

18. For the meaning and value of paleosol maturity stages and paleosol chronosequences see Harden 1982, van Andel 1998, Magaldi and Tallini 2000, Retallack 2001, Runnels and van Andel 2003.

19. That is, excluding the bifaces that I discovered (see below), which were deemed important enough to be collected.

Considering that all previous researchers report that zone A is archaeologically sterile, most of my efforts concentrated on the examination of zones B and C. In the few places where the transition from zone A to zone B was identified, it was confirmed that the upper part of zone A follows an irregular line, as it is noted also by Tippet (Dakaris *et al.* 1964) and Runnels and van Andel (1993a). Presumably, this could mean that, after the accumulation of zone A-sediments had ceased, followed a period when no deposition, but instead, erosion was prevailing; sedimentation resumed again with the accumulation of zone B sediments directly on this eroded surface. An immature paleosol and a desiccation band, both indicating relatively brief hiatuses in the sedimentation, mark the boundaries of zones B and C. However, in this latter case (transition from zone B to C; App. I: 4) there is no 'uneven surface' formed as in the case of the junction between zones A and B mentioned above. This probably suggests that when sedimentation of zone B halted, the land surface was stable enough for soils to start forming, and it was either not affected by erosion at all, or erosion was too mild to have a significant impact on the morphology of the exposed surface. Alternatively, this difference between the two transitional parts of the sequence (A-B and B-C) may be seen as representing differences in the palaeotopography: early in the history of the polje, sediments of zone A were being deposited directly on the limestone bedrock and, although the floor of the newborn polje would have been relatively flat, it still involved irregularities inherited by the original, jagged morphology of the karst. However, after deposition of zone A, and especially upon and after deposition of zone B, the floor of the basin was already smoothed and leveled by slow, low-energy sedimentation.

Indeed, zone B deposits are characterized by abundant grey veins, mottles and gley streaks (App. I: 6, 7); gleying indicates water-logging, and the subhorizontal laminations first stressed by Runnels and van Andel (2003) provide firm evidence that zone B was mainly deposited under standing water, hence under conditions of low-energy, allowing for fine stratification. As regards the two "moderately mature, truncated paleosols" recognized by Runnels and van Andel (*ibid.*, 70) within the main part of zone B, only one (most likely the upper) could be tentatively iden-

tified (App. I: 4a). The association with gravel lenses and flint fragments ("many of them Palaeolithic artefacts": *ibid.*) could not be verified for that paleosol. However, it has to be appreciated that paleosol occurrences are very localized and hard to discern. In this badland landscape, paleosols are discontinuous, patchily exposed and truncated; moreover, their formation upon sediments that were already red makes their recognition very difficult even for the most experienced eyes - a fact that largely explains why both teams from Cambridge were essentially silent about the paleosols occurring in redbed sites²⁰. Apart from paleosols, the other major indication of dry, subaerial surfaces comes in the form of desiccation zones and bands of black (manganiferous) concretions that indicate oxidation of sediments; fortunately, these are more conspicuous than the paleosols (App. I: 8, 9). Clear signs of desiccation denote in a circular fashion the boundaries of a grey layer resting upon deposits of zone B, in a restricted area of a few square meters in the central part to the east of the main divide (App. I: 10, 11). This layer was not identified in any of the exposed cross-sections, but was seen only in horizontal association with zone B deposits and it is unlikely that it corresponds to the layer of 'pale gray silt' that is noted in the stratigraphic scheme of Runnels and van Andel, because the latter is shown to be included in zone A (see cross-section of Fig. 4.9). A concentration of patinated lithic artefacts of Middle Palaeolithic morphology was observed lying on that layer (App. I: 12). The surface condition and spatial distribution of the flints does not point to clustering due to the action of water, and, in contrast to other artefact clusters seen occasionally in gully floors, this one seems indicative of low-energy uncovering and minimum horizontal displacements as it would be, for instance, in the case of deflating processes. However, without the aid of excavation and as this is an assemblage seen on the surface and not in cross-section, very little can be said with certainty about its taphonomic significance.

20. An additional explanation could be that (some of) the soil profiles were not exposed in the 1960's, but were revealed only later, in the 1990's, due to erosion (*cf.* Runnels and van Andel 1993a, 200).



Fig. 4.10 Valtos Kalodiki: an active polje, exemplifying how Kokkinopilos, Morphi, Karvounari and the other 'redbed sites' would have been in their early stages of development, *i.e.* before the accumulation of thick, redeposited *terra rossa* fills, and before uplift, stream incision and dissection. Note that, despite the overall flatness of the polje's floor, water is not retained equally throughout the extent of the depression

Although seen in a horizontal, rather than vertical association with the stratigraphy, it can be suggested that this layer most probably belongs to zone B. Considering the evidence discussed previously about periods of subaqueous deposition alternating with intervals of subaerial exposure of the land-surfaces, it is reasonable to assume that the grey colour of this layer is a result of anaerobic (reduction) conditions and bleaching by water, whilst the circular feature of desiccated sediments marks the boundaries of a dry surface, most likely the periphery of the water-logged area. Notably, the desiccated surface continuous into zone B, away from the grey outcrop, marking a substantial hiatus. If this was indeed a small, localized pond inside the broader lacustrine environment of the polje, it could prove to be very informative for both the evolution of the polje and the taphonomic circumstances of the deposition of the lithics. For instance, when we envisage the polje of Kokkinopilos as a lake that was at times filled with water and at other times drying out, it should be taken into consideration that such alternations might have had different and varying life-histories in both space and time: whilst at one locality a deep depression would be able to retain water for a considerable time-span and/or in a large spatial extent, draining might have been more successful in the temporal and/or spatial

dimension for another, shallower locality. Such a situation does not necessarily require large differences in the relief of the two localities mentioned in this example, as subtle topographical differences may well do the work. This picture can be seen in the existing active poljes and loutses of Epirus: whereas their floor would be described as generally 'flat', slight differences in their topography make up for a complex setting of marshy spots neighbouring dry surfaces (Fig. 4.10). For loutses, which are rain-fed and hold water mostly in winter and spring, it can be argued that a water-logged place may change to dry land seasonally. Poljes tend to retain water for longer periods and the largest ones form permanent lakes now. Yet the same hypothesis may be invoked also for poljes, if only in a longer-term consideration. As a general scheme, we can assume that poljes preserved perennial water (*cf.* van Andel and Runnels 2005). However, in the dynamic environment of active tectonics and karst landscapes of Epirus, 'permanence' of water is also rather relative spatially, geomorphologically speaking. In the long-term and within the morphological borders of a polje, a localized tectonic disruption is able to lift a locality high enough for it to be above groundwater-level and dry out; alternatively, a solution hollow may collapse if an internal threshold is crossed, thereby deepening

or enlarging a depression, turning it from a previously seasonally-dry surface into a more sustainable water-collecting feature. In short, dry-wet alterations inside poljes may have had a dynamic temporal and spatial character, and this could be exactly the story which the gray layer may prove to be revealing.

In the main part of Kokkinopilos, the contact between zones B and C was found at *ca.* 136 m asl (App. I: 13), confirming the altitude of the boundary shown in fig. 3.17 of Runnels and van Andel (2003). The mapping of this contact could not be extended to the entire area of the site and was restricted to a small part of the central area, because of the brief time available and the immense difficulties arising due to the badland morphology, the often hardly discernible differences in colour, and the fragmented occurrence of the paleosol that can be used as a stratigraphic marker for distinguishing the contact between the two zones (App. I: 14). Nevertheless, as noted earlier, at first sight this contact appears as a rather even line, suggesting perhaps a quite smooth, low-gradient morphology in this stage of the polje's evolution. Above this contact lies zone C with a maximum thickness up to 8-10 meters, displaying also diffuse grey veins that can be interpreted as signs of gleying by fluctuating water levels (App. I: 15; *cf.* Runnels and van Andel 2003, 70, 73). The mature paleosol capping zone C and dated at 91 ka (hereafter, it will be referred to as 'Mid-Palaeolithic Soil', as it was designated for convenience by Runnels and van Andel 1993a, 198) is clearly visible on the east-facing slope of the main divide, but appears also in varying thicknesses on parts of the eastern slope, at the foothills of the limestone ridge (App. I: 16). Neither flint fragments nor artefacts were found in direct association with this paleosol, as claimed by Runnels and van Andel (1993a, 2003). But again, as mentioned earlier with regard to the paleosol(s) of zone B, this 'absence of evidence' may simply be an artefact of the limited time available for investigations and/or of the fragmented nature of paleosol occurrences (*e.g.* App. I: 17a) -let alone the on-going erosion. Furthermore, it could not be ascertained whether the 'Mid-Palaeolithic Soil' was formed directly on zone C deposits or *on a layer overlying zone C* (App. I: 18), the latter layer perhaps coinciding with 'Layer D' of Bailey *et al.* (1992). According to Bailey and colleagues (*ibid.*, 140) layer D is a *soil* "which locally overlies either

Layer B or Layer C deposits". The latter researchers also note that "the top of this soil forms the old land surface, which can be traced over large areas and which was certainly present in Roman times" (*ibid.*, 141). Regardless of whether this 'soil' ('Layer D') is the same entity as Runnels and van Andel's 'Mid-Palaeolithic Soil', or a separate (*sedimentary*) body underlying the 91 ka-soil, the above-cited proposition of Bailey *et al.* seems to contradict their view of widespread erosion and reworking of the deposits (Papagianni 2000, 30). Moreover, the next sentence following the aforementioned assertion of Bailey *et al.* (*ibid.*) states that "Arrowheads attributed to the Bronze Age, pottery, and Mousterian artefacts including disc cores are found on this surface". There is definitely some confusion here. Above 'Layer D' of Bailey and colleagues (1992) and/or above the 'Mid-Palaeolithic Soil' of Runnels and van Andel (1993), there is the modern, still-forming soil that we can call 'topsoil' for convenience. As noted by both Higgs' team (Dakaris *et al.* 1964, 214, 222) and Runnels and van Andel (1993a), unpatinated artefacts of either Bronze Age or Upper Palaeolithic morphology appear only *on* (and locally inside) *this topsoil* (App. I: 19). Consequently, it should not be confused with the mature soil dated at 91 ka, in which only patinated artefacts (attributed to the Middle Palaeolithic) occur (*cf.* Runnels and van Andel 1993a, 2003). To add to confusion, Harris and Vita-Finzi (1968, 539, 541) also talk about a "zone D" deposit between zone C and the modern topsoil; they regarded it as an alluvial deposit, correlative to Vita-Finzi's 'Younger fill' (of post-Roman age; Vita-Finzi 1969). In any case, it could not be securely assessed whether this is a fourth sedimentary layer upon which the 'Mid-Palaeolithic soil' was formed. Interestingly, a Bt horizon comparable in maturity with that of the 'Mid-Palaeolithic Soil' -as it is exposed in the east-facing slope of the main divide- was seen in the west-facing slope overlying a separate layer that rests here discomformably on zone C (App. I: 16b). It could not be ascertained whether this is a pedogenic horizon (Btk or Bc?) or a relict bed from sedimentary parent materials not yet obliterated by soil formation. In contrast to the columnar structure of the overlying Bt horizon, this 'layer' displays fine bedding, but its overall appearance (structure, texture, colour) differs substantially from the alleged 'Layer D' seen in the western slope; its boundary with the overlying Bt



Fig. 4.11 Biface found on the surface of reworked deposits

horizon is rather gradual, whilst the truncated appearance of the boundary with zone C indicates a hiatus (see also App. I: 17).

During my first visit at Kokkinopilos I found a biface lying on the surface (Tourloukis 2009), a few meters from the place where Runnels and van Andel (1993a) discovered the Micoquian handaxe and at *ca.* 127 m asl, namely at about the same stratigraphic level as the latter find (Fig. 4.11). The specimen is a patinated “amygdaloid à talon” (Debénath and Dibble 1994) with a cortical base, made on bluish-grey, fine-grained flint; typologically, it can be described as a typical Acheulean biface (Fig. 4.12). As it is shown in Fig. 4.11, the sediments with which the biface is associated belong to *reworked* deposits, most

probably deriving from zone B and most likely pertaining to the fill of an erosional gully (App. I: 20). That being said, the artefact is preserved in a mint condition, which suggests minimum transport (App. I: 21b).

Another biface (or, ‘bifacial core’; Fig. 4.13) was discovered during my second visit at the site, this time together with the geologist P. Karkanias. The artefact seems to have been made on a flake-blank and it displays a flat bifacial retouch, whereas on one side, large parts have been left unretouched and there is a breakage on the left lateral edge; the base looks as if it has been deliberately left unworked, or, alternatively, it broke in the process of manufacture and it was then left unretouched. The tip is triangular in

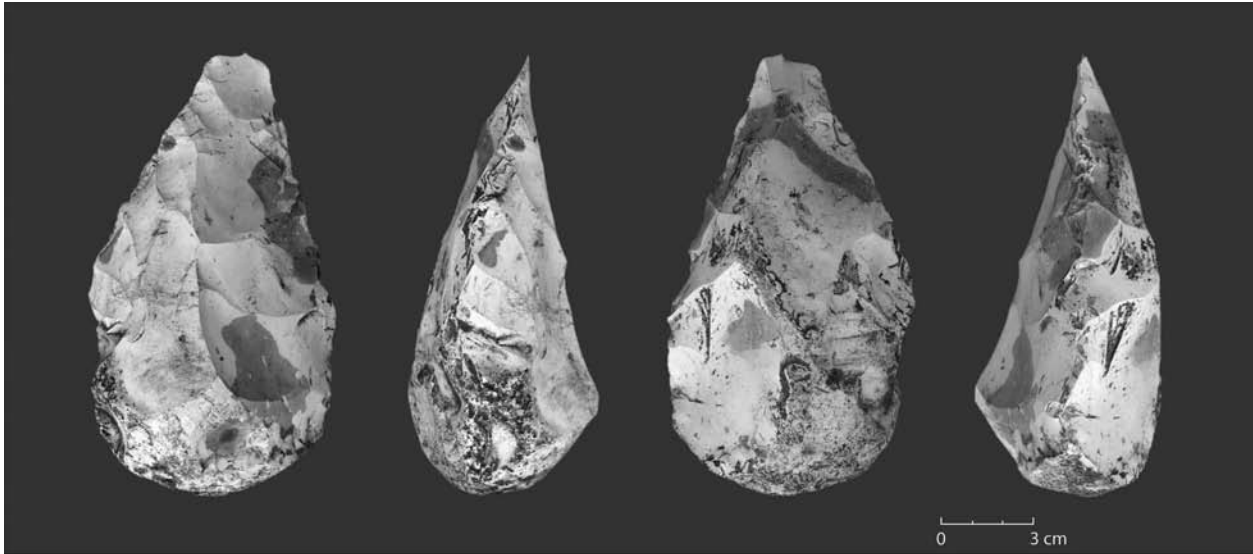


Fig. 4.12 The biface shown in Fig. 4.11

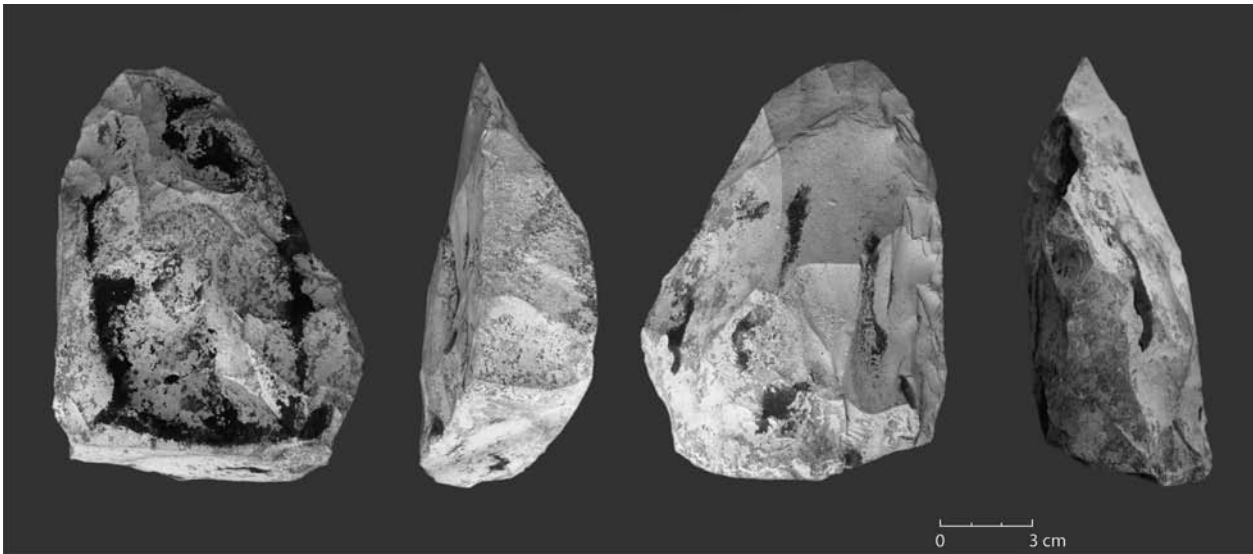


Fig. 4.13 Biface found *in situ*, embedded in deposits of zone C

section, one cutting edge is sinuous, while the other is essentially straight, largely because of the break that occurs there. Metrical data classify it to Bordes' 'thick bifaces' with a cordiform aspect²¹. The specimen is in a fresh to mint condition, with its cutting

edges still sharp and the ridges of the flake-scars clearly visible, albeit slightly worn locally. It is heavily patinated and displays red stains on both surfaces due to contact with Fe- and Mg-oxides. Overall, there are no signs of weathering, polishing or abrasion, and the general appearance of the artefact disproves the case of significant rolling, neither by running water

21. Length: 13.02 cm; Width: 10.00 cm; Thickness: 4.9 cm; distance from base to maximum width: 4.4 cm; width at midpoint of length axis: 8.6 cm; width at $\frac{3}{4}$ of the length from the base: 6.7 cm; Elongation Index: 1.30; Flatness Ratio: 2.04;

location of maximum width: 2.95; roundness of the edges: 0.86; Pointedness: 0.67



Fig. 4.14 The biface of Fig. 4.13 as it was found upon discovery

nor by large-scale gravity-induced downslope movement.

The artefact was found lying horizontally with half of its surface buried by the sediments, embedded within *non-reworked* deposits, in the upper part of zone C and at an altitude of 140 m asl, namely some five meters below the ‘Mid-Palaeolithic Soil’ (Fig. 4.14; App. I: 22). Gleyzation of the sediments occurred after the deposition of the artefact and the drab halos wrap around the specimen. The condition of the artefact, as described above, as well as the fine bedding of the deposits and the lack of any other signs that could indicate reworking, altogether suggest that this biface is geologically *in situ* (App. I: 21a). When the findspot was later re-visited for sediment sampling (see below), a flake was also found *in situ* in the same sediments (App. I: 33b).

The recently discovered bifaces add two more implements to a meager sample of five in total from Kokkinopilos: apart from the Micoquian handaxe of Runnels and van Andel (1993), another, very rolled and worn biface has been found on the surface

(Adam 1998), whilst there is also a handaxe-tip found during the early investigations of E. Higgs (1963; Dakaris *et al.* 1964, 219). Excluding the bifacial implements (most of which are handaxes) that have recently been reported from Crete (Strasser *et al.* 2010), the bifaces from Kokkinopilos account to about half of the total number of published bifaces/handaxes recovered thus far from the entire Greek territory. Bifaces cannot be used as chronological markers (see section 2.1) and it is not possible to ascribe the Kokkinopilos specimens to a (late?) Lower or (early?) Middle Palaeolithic techno-complex. However, it is beyond doubt that the artefact reported by Runnels and van Andel (1993a) as well as that of Fig. 4.12 (this study; Tourloukis 2009) can be described as *bifaces*; specifically, in most publications and textbooks of lithic typology, such implements are characterized as Acheulean bifaces. Recently, Otte (2010) argued that these specimens are not (Acheulean) bifaces, but, rather, (Mousterian) bifacial foliates. Unless Otte has published his own definition of foliates and bifaces (that I am not aware of), it is hard to see what he means here. If one compares Fig. 4.12 (this study) and figures 2 and 3 of Runnels

and van Andel (1993a) with figure 21 of Dakaris *et al.* (1964), in which five foliate pieces from Kokkinopilos are depicted, one can see that the specimens are clearly different. In short, to my eyes, the artefact found by Runnels and van Andel and that shown in Fig. 4.12 are Acheulean bifaces, the artefact shown in Fig. 4.13 is also a biface or bifacial core; none of them should be confused with foliates and none of them acquires a chronological value because of its morphology. Their importance lies in their stratigraphic significance.

Then, how do these new bifaces contribute to the discussion on the reworked vs. *in situ* finds from redbed sites in general and Kokkinopilos in particular? The biface found associated with reworked sediments will detain us first. Indeed, the site is a treeless badland dissected by numerous rills and gullies. There are many parts at the site where modern in-fills of reworked deposits can be discerned through the loose texture of the sediments, the darker brownish colour, the overall structure of the deposit (*e.g.* channel and scour fills following the present topography) as well as the absence of pedogenic features (*e.g.* gleying). Considering too that the redbeds are virtually stone-free (apart from the flints), it is important to note that, wherever limestone fragments occur, they are usually associated with reworked deposits (App. I: 23).

Nonetheless, it needs to be stressed that it can occasionally be extremely difficult to differentiate between intact deposits and reworked sediments of a gully fill. It is undoubtedly easier to identify a 'modern' fill of, for example, a few hundred- or thousand-years-old, as seems to be the case with the reworked sediments of the first biface; than a reworked deposit that dates back to a hundred thousand years ago or more. In the course of time, a very old gully infill could have been subjected to the same pedo-sedimentary processes affecting the surrounding (intact) deposits as well, thereby acquiring characteristics similar to those of undisturbed sediments (*e.g.* App. I: 24). Obviously, in such cases the distinction can be attested only with the resolution provided by excavation, and even then, the aid of micromorphology and laboratory analyses might be deemed indispensable. For instance, to what degree can the effects of gleying, affecting an originally undisturbed deposit, be retained when the same deposit becomes reworked?

Or, alternatively, what are the qualitative differences between the mottling of an *in situ* deposit and that of a reworked fill, assuming that the latter has been mottled *after* being re-deposited into a secondary location? Such concerns have been at best briefly mentioned by previous researchers (*e.g.* Bailey *et al.* 1992: 141 with regard to Higgs' Site β) and they have certainly not been resolved, whereas other issues have not been yet addressed at all. For example, gleying (or, gleization) is a general term used to describe processes that produce these bluish-grey colourations due to water-logging, when micro-organisms reduce oxidized minerals (*e.g.* iron hydroxides and oxides such as hematite, which cause the characteristic red colour) under anaerobic conditions (Retta-lack 2001); although originally coined to characterize *soils*, the same term is used (Runnels and van Andel 1993a; this study) to describe (parts of) the Kokkinopilos *sediments*. In all likelihood, most of the Kokkinopilos deposits accumulated within the zone of water-table fluctuation, hence the drab-haloed root traces and grey mottles alongside ferruginous coatings. In places, iron-manganese oxides are abundant, forming hardpanized zones such as that shown in App. I: 8, 9, which are macroscopically similar to some paleosol horizons at Morphi (App. I: 32; see also App. I: 28, 29 for an analogous zone in the redbeds of Ayia). Should these hardpans be regarded as pedogenically acquired features, such as petroferic horizons developed by precipitation of hematite-cements, which were gleyed during saturation and then became subaerially exposed, indurated and stained with Mn- and Fe-coatings? Moreover, would it be possible to distinguish between *groundwater gley* (due to high water-table) and possible *surface-water gley* from stagnant water (due to impeded drainage *e.g.* by the impermeable clays and/or during periods of excessive rainfall)? Potential geochemical signatures may help to answer such questions and clarify which features are the results of pedogenic processes and which ones resulted from syn/post-depositional sedimentary processes of chemical weathering affecting buried and/or exposed sediments. In turn, this sort of clarifications will enhance our understanding not only when distinguishing between soils and sediments, especially since pedogenesis is now accepted to occur also in shallow submersed environments (*e.g.* Demas and Rabenhorst 2001); but also when assessing rates of soil formation versus sedimentation

rates. The latter appraisal (how fast was deposition relative to soil formation) is crucial in explaining how artefacts became incorporated into paleosols (see van Andel 1998, 383; Runnels and van Andel 2003, 93-94); and it is also related to assessing the hiatuses reflected in the evidence for breaks in the sedimentation. A better knowledge of all the above is also needed for the reconstruction of the palaeotopography of the site, the determination of the poljes' (active) margins and the evolution of both of the latter across space and time. Needless to stress, these queries are closely related to the main archaeological problems -a fact that is dramatically illustrated by the history of the relevant, previous interpretations.

Evidently, many issues related to the older investigations will remain unresolved, as with the case of Higgs' test trenches, for which the published accounts do not permit a proper re-evaluation. Papaigianni (2000, 71) remarks that the excavation notebook and a report written by the excavator of the trench at *Site α* argue that the excavated deposits had been reworked –a view that was afterwards maintained by Bailey *et al.* (1992); and her own analysis of the lithic material from *Site α* suggested that the artefacts from that trench were not found *in situ*. Papaigianni (*ibid.*, 73) considers the lack of refits in *Site β* as supporting the claims of Bailey *et al.* (1992) that the deposits are here reworked, too. However, the presence of refits does not warrant an undisturbed context and, similarly, the absence of refits is not in itself strong evidence for a disturbed context. In any case, Higgs explicitly mentions the presence of “a more recent erosion gully cut into [...] Zone B” (Dakaris *et al.* 1964, 215) which he distinguishes from the rest of the deposits in that trench; this distinction is clearly visible in the published photograph of the trench and it supports the opinion that, in an excavation, it is easier to recognize reworked sediments. Notwithstanding this clear distinction made by Higgs, it could be very well possible that, similar to the case of *Site α*, the trench of *Site β* was also cut in redeposited sediments.

Is it then true that none of the artefacts from Kokkinopilos are geologically *in situ*, as Bailey *et al.* (1992) argue? The recovery of the second biface from what macroscopically are undisturbed deposits seems to prove otherwise: it supports the argumenta-

tion of Runnels and van Andel for the presence of artefact occurrences in the stratigraphic sequence. Even if we disregard Higgs' claims for the identification of ‘chipping floors’, the research carried out recently (Runnels and van Andel 2003; this study) provides strong evidence for *in situ* lithic occurrences in zone B, which is the thickest of the three stratigraphic zones, the one most widely exposed and perhaps most valuable for the archaeology of the early Palaeolithic. The recent recovery of another biface (Tourloukis 2009) and a flake from undisturbed deposits of zone C may be viewed as *extending the claims for stratigraphic integrity to this uppermost zone as well*; furthermore, these finds suggest that zone C is not archaeologically sterile, as postulated by Runnels and van Andel (1993, 200). That being said, the re-evaluation of the earlier arguments for *in situ* finds, together with the observations made during the latest revisits, altogether serve as a warning against premature generalizations. Large parts of the site -and perhaps most notably those consisting of zone B deposits- seem to be stratigraphically undisturbed, but other parts are covered by sediments that have been redeposited in secondary locations.

Together with the finding of some more artefacts from undisturbed deposits, my assessment of the stratigraphy (and its overall integrity) at Kokkinopilos can be seen as having wider implications for all redbed sites of Epirus and the discussion about their archaeological contexts. Conceivably the closest parallel to Higgs' ‘chipping floors’ that was observed during my revisits is the concentration of lithic artefacts that was documented for the grey layer of Kokkinopilos' zone B deposits, mentioned above. At least one artifact concentration similar to (but more extensive than) the latter was found in Mikro Karvounari, another redbed site some 30 km to the north-west of Kokkinopilos (App. I: 25). In 2005, I surveyed this site as a member of the ‘Thesprotian Expedition’ survey team; there, we encountered a ‘carpet’ of thousands of lithic implements in a locality which was later given the code-name PS23/Unit 5 (App. I: 26; see <http://www.finninstitute.gr/Thesprotia/texts/Report.htm>, for preliminary reports). The locality was intensively sampled and a preliminary analysis of a small part of the assemblage (*ca.* 2000 specimens) was undertaken by the author together with O. Palli (32nd Ephorate of Prehistoric and Clas-

sical Archaeology, Greek Ministry of Culture). The greatest bulk of the assemblage(s) collected from Karvounari consists of -rather variably, yet mostly heavily patinated- artefacts of Middle Palaeolithic typology (*cf.* Papakonstantinou and Vassilopoulou 1997), whilst most of the few unpatinated pieces can be attributed to later periods (Upper Palaeolithic, Neolithic, Bronze Age). The material includes also pieces that lack Mousterian technological characteristics and, had they been found in an excavation, they would fit well to a Lower Palaeolithic context, but nothing more can be said with certainty. Evidently, a mixture of artefacts from different periods is almost definite as regards the surface collections, but in other parts of the site I observed stratified occurrences of lithics in apparently undisturbed deposits (App. I: 27). Test trenches were opened in the aforementioned locality in 2008 but the results have not been published yet. The excavations are expected to shed light to these enigmatic artefact concentrations, which locally include pieces that stand out as outliers with regard to the rest of the assemblage, in terms of their lack of patina, their typo-technological characteristics and often the raw material as well.

Flint fragments and possible worked pieces were seen embedded also in the *terra rossa* fill of the raised loutsa of Ayia (App. I: 28, 29), but without the relevant permission it was not possible to scratch the surface of the deposits in order to remove the flints and examine them; therefore, the claims of Runnels and van Andel (2003, 75) for artefact-bearing layers could only tentatively be confirmed. Equally tentative is the identification of artefact occurrences in the thin bands of fine to medium flint gravels and sand, intercalated within yellowish-red *terra rossa* sediments in another raised and dissected polje at Morphi (App. I: 30). Here, the redbed zone (*ca.* 12 m-thick) is indeed very similar to zone B of Kokkinopilos (Runnels and van Andel 2003, 72), is marked by paleosol horizons and it overlies a 2.5-m-thick tephra deposit that has been dated by Ar-Ar to *ca.* 374 ka (App. I: 31, 32; Pyle *et al.* 1998). Importantly, the dating of the Morphi tephra *challenges the view of Bailey et al. (1992) that the redbeds of Kokkinopilos (and of the other redbed sites) are much older than Middle Pleistocene* (Pyle *et al.* 1998, 285). Furthermore, I did not identify any alluvial deposits in none of the aforementioned poljes and loutsas, in contrast

to Bailey *et al.*'s (1992) arguments for streams incising the allegedly pre-Middle Pleistocene redbeds and re-depositing the artefacts. The bands of fine gravel seen at Morphi -and occasionally in other poljes as well- are too thin, rare and patchy to indicate major alluvial events; instead, following Runnels and van Andel (2003), I consider them as the depositional products of small ephemeral streams or thin, distal debris flows that sporadically interrupted an otherwise slow sedimentation by low-energy agents. The fact that such gravel bands are reported to occur at the margins of the main deposits at Kokkinopilos (Harris and Vita-Finzi 1968, 539) comes in support of the above interpretation.

4.5.5 Conclusions and discussion

The investigations of Runnels and van Andel, and most prominently their discovery of a handaxe stratified in undisturbed sediments, revived the claims first expressed by Higgs and his team for *in situ* lithic occurrences at Kokkinopilos²², and provided for the first time convincing arguments for stratified lithic occurrences that can be attributed to the Lower Palaeolithic on chronostratigraphic grounds. Preliminary results from the latest surveys carried out by the author (Tourloukis 2009) suggest that undisturbed sediments occur over large -if not most- parts of the site. In accordance with Runnels and van Andel (2003), there is ample stratigraphic and sedimentological data pointing to the low-energy depositional environment of a lake, which was formed in a tectonic basin (a polje) and was at times drying out either locally or entirely. Signs of gleying and mottling attest to sedimentation under wet conditions, whilst paleosols, black colour bandings and desiccation surfaces mark depositional breaks and designate subaerially exposed surfaces upon which artefacts (could) have been discarded. In other words, there are depositional units in stratigraphic order bounded by unconformities and marked by paleosols that may contain geologically *in situ* archaeological finds. Artefacts asso-

22. Note that, with the exception of the handaxe found by Runnels and van Andel (1993), a biface found by E. Adam (1998), as well as the two new bifaces reported here, no other documented collection of material took place in Kokkinopilos after the 1960's (Papagianni 2000, 70).

Site	Sample	Method	Age (ka)	References
Kokkinopilos <i>Site Beta, Layer A</i> (= zone A)	KOK 13	TL	> 150	Bailey <i>et al.</i> 1992
Kokkinopilos <i>Site Beta, Layer B/C</i> (= zone B)	KOK 14	TL	> 150	Bailey <i>et al.</i> 1992
Kokkinopilos uppermost paleosol	VA93-05	TLr	91 ± 14	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003
Morphi tephra layer	20A-A	40Ar-39Ar	374 ± 7 (plateau age, interpreted as the eruption age)	Pyle <i>et al.</i> 1998
Ayia upper paleosol	VA94-27	IRSLa IRSLr	6.1 ± 0.6 7 ± 1	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003
Ayia lower paleosol	VA94-29	IRSLa IRSLr	65.5 ± 6.8 84 ± 11	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003
Ayia lower paleosol	VA94-30	IRSLr	83.1 ± 12	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003
Alonaki redeposited terra rossa	VA94-32	TLa TLr IRSLa	10 ± 2 10 ± 2 9 ± 2	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003
Loutsa surface paleosol	VA94-36	TLa TLr IRSLr	59 ± 9 51 ± 8 52 ± 8	Zhou <i>et al.</i> 2000 Runnels and van Andel 2003

Table 4.1 Radiometric dates for redeposited *terra rossa* ('redbeds') and/or paleosols formed on redbeds. The table includes all published accounts up to 2009. TL = thermoluminescence, IRSL = infrared stimulated luminescence, a = additive method, r = regeneration method, Ar-Ar = Argon-Argon radiometric dating

ciated with paleosols and/or desiccation surfaces indicate the presence of hominins when the land-surfaces of the poljes were dry and stable, whilst artefacts found in sediments that were deposited underwater point to exploitation of the poljes (obviously, their margins) during wet conditions. The fine-grained nature of the sediments and the overall condition of the recovered artefacts suggest transportational agents of very low energy and hence support the claims for minimum transport of the lithics from their original places of discard. Clearly, further investigations are much needed in order to assess site formation processes and the possibility of discovering *archaeologically in situ* assemblages (primary contexts). At the moment, however, what is most important (and implied in the assertion of *geologically in situ* finds) is that, for the appropriate, undisturbed localities, the dating of the engulfing sediments could furnish age-estimates for the associated artefacts.

Bailey and colleagues report on two TL-dates of >150 ka for samples taken from sediments of zone A

and zone B at Kokkinopilos, which they regarded as inconclusive, if not suggesting that sediments at both sampling sites are older than 150 ka (Bailey *et al.* 1992, 141-142). Excluding the aforementioned dates, thus far the available dating controls for Kokkinopilos and the other redbed sites are restricted to: the date of 91 ka for the paleosol capping the sequence at Kokkinopilos, the (Ar-Ar) 374 ka-date of the tephra directly underlying the redbeds at Morphi, as well as a few more dates from the sites of Ayia, Alonaki and Loutsa, the latter ranging from the middle Late Pleistocene up to the early Holocene (Table 4.1; Zhou *et al.* 2000; Runnels and van Andel 2003: Table 3.10). All of the most recent dates are the outcomes of a thermoluminescence (TL and IRSL) dating program carried out by Runnels, van Andel and colleagues (*ibid*), which provided pioneering evidence for the potentials and the restrictions in dating the open-air sites of Epirus (see also Zhou *et al.* 2000 for more details on the comparison between the two methods and their limitations when applied in the context of karst basins). Following this line of re-

search and considering that the chronological bracketing of the deposits at Kokkinopilos has been the core of the heated debate, it was decided to sample carefully selected sediments at this site and date them with the method of Optically Stimulated Luminescence. Of the six samples taken in total, three have been submitted for dating at the Netherlands Center for Luminescence (Dr. J. Wallinga), and those were taken from: 1) zone C, some centimeters below the 'Mid-Palaeolithic Soil', in the uppermost part of the sequence; 2) the findspot of the biface in zone C, and 3) deposits of zone B, stratigraphically and spatially close to the findspot of the 'Micoquian' handaxe (App. I: 33). Results are still pending and luminescence dating proved to be challenging, as the quartz OSL signals were in saturation. Given the saturation characteristics and environmental dose rate, a minimum age of 40 ka is preliminary indicated, while additional experiments are underway in order to obtain a more precise chronological estimate (J. Wallinga, pers. comm. 2010).

The refinement of the Kokkinopilos chronostratigraphy will have major implications for the interpretation of the redbed sites in north-west Greece. Any conclusive results from the latest OSL dating, which is still in progress, will test the earlier TL-date for the paleosol capping the sequence, and, as long as the actual age of the sediments does not exceed the limits of this method, they may provide *the first direct chronological evaluation* not only for the deposits of zones C and B, but also for the newly discovered biface from zone C, as well as that found by Runnels and van Andel in zone B. Thus, the results may help to substantially refine the age estimate for the 'Micoquian' handaxe, which is as yet the only stratified implement that can be attributed to the Lower Palaeolithic on stratigraphic grounds. In that sense, even if the stratified biface from zone C cannot be itself attributed to the Lower Palaeolithic, it does acquire a direct stratigraphic value of great importance with respect to the discussion on the integrity of the site, as well as an indirect merit regarding the placing of the Lower Palaeolithic find(s) into a local chronostratigraphic scheme. In turn, an improved local chronostratigraphy at Kokkinopilos can serve as the basis for regional chronostratigraphic comparisons and correlations between the numerous redbed sites of Epirus. Effectively, this would advance the assessment of

geological interpretations and at the same time it will set 'anchor points' for resolving long-lasting archaeological inquiries that cannot be otherwise deciphered. For instance, typological characteristics, degree of patination and raw materials of artefacts are not reliable markers for solid interpretations and provide only first-order indications for seriating individual artefacts and/or assemblages into a chronological order, let alone for spatial patterns and inter- and intra-site distributions²³ (cf. Papagianni 2000).

Establishing a chronostratigraphic framework for the open-air sites of Epirus becomes a primary research objective with implications that may be seen as reaching beyond the geographical boundaries of this district, considering that Greece is still lacking such frameworks for any pre-Mousterian evidence. Epirus remains the best-studied region in Greece in terms of Palaeolithic investigations and it has also provided invaluable palaeoenvironmental data sets, such as the long pollen records from Lake Ioannina and the glacial record of Mountain Tymphi, both of wider (at least European) significance (e.g. Tzedakis 1994; Hughes *et al.* 2006c; see section 6.2). It is indeed the richest area in Palaeolithic remains, and, as Runnels and van Andel rightfully note (2003, 125), this can no longer be attributed to a lack of systematic research elsewhere in Greece. For instance, a total number of *ca.* 30 findspots in Thessaly has yielded fewer than 1,000 lithic artefacts, whilst a similar number of findspots discovered during the Nikopolis survey project alone produced artefacts 100 times more numerous; and such comparisons can be even more dramatic when they involve surveyed regions of southern Greece (*ibid.*).

Based on the accounts of Bailey *et al.* (1997) and Runnels and van Andel (2003), it can be estimated

23. A dirt-road that has cut through the Kokkinopilos deposits (see App. I: 22b) was paved with gravels of unknown origin that contain numerous 'fresh' and unpatinated flint fragments and nodules, a lot of which are being eroded down to the gullies. Although the presence or absence of patination works well as a thumb-rule, the case of the flints deriving from the dirt-road shows how tentative and illusive such associations may be (e.g. when considering unpatinated artefacts as of Upper Palaeolithic age). For a more thorough account on the issues around patination see Papagianni 2000.

Period	Open-air		Rockshelter / Cave		Total	
	N	%	N	%	N	%
Lower Pal.	3	2.4	-	-	3	2.2
Middle and Upper Pal.	121	97.6	9	100.0	130	97.8
Total	124	100.0	9	100.0	133	100.0

Table 4.2 Distribution of open-air sites and rockshelters of Epirus by archaeological period. Data compiled from Bailey *et al.* 1997: Table 27.3, and Runnels and van Andel 2003: 134. Note that this is not meant to be a precise account in the first place, and there may be slight mistakes in the actual number of the 'Middle and Upper Palaeolithic' sites (most probably there may be a few more), due to small inconsistencies arising from generalizations made in the published sources. 'Middle and Upper Palaeolithic' includes also sites of Palaeolithic age that were not datable to a finer resolution

Period	Stratified / Datable				Non- Stratified / Non-Datable				Total	
	Open-Air		Rockshelter / Cave		Open-Air		Rockshelter / Cave		N	%
	N	%	N	%	N	%	N	%		
Lower Pal.	3	30.0	-	-	-	-	-	-	3	2.2
Middle and Upper Pal.	7	70.0	6	100.0	114	100.0	3	100.0	130	97.8
Total	10	100.0	6	100.0	114	100.0	3	100.0	133	100.0

Table 4.3 Distribution of stratified / datable sites vs. non-stratified / non-datable sites by archaeological period and site type. As in the case of Table 4.1, this account should be regarded as an approximate one, aiming to portray general patterns. Data compiled based on Bailey *et al.* (1997) and Runnels and van Andel (2003)

that the total number of Epirote sites dating to the Palaeolithic amounts to 133 (Table 4.2). Of these 133 sites, only three produced material that was tentatively assigned to the Lower and/or 'Early Palaeolithic', namely Kokkinopilos, Alonaki and Ormos Odysseos (see 4.5.6 for the latter two sites). In total, it is only sixteen sites where the material was found stratified *and/or* could be assigned an age-estimate with either relative or absolute dating techniques (Table 4.3): six of these are rockshelters and caves, the remaining ten being the open-air sites of Kokkinopilos, Alonaki, Ormos Odysseos, Ayia, Rodaki, Galatas, Kranea, Anavatis, Loutsa and a site in the Voidomatis Basin²⁴ (Bailey *et al.* 1997; Runnels and van

Andel 2003). All of the latter ten sites, but also most of those where the material was not found stratified and/or was not datable, are associated with localities of redeposited *terra rossa*, found either inside poljes/loutsas or on their margins.

Including rockshelters and caves, the sites with stratified/datable material account for 12% of the total (16 out of 133); if we exclude rockshelters and caves, then the number falls to 7.5%. Notwithstanding the richness of Epirus in Palaeolithic finds and putting aside issues regarding overall research biases (*e.g.* survey strategies, such as sampling methods, survey intensity and coverage, documentation etc, which are on the whole difficult to assess; *e.g.* see Bailey *et al.* 1997) both numbers can be regarded as vividly reflecting the *general rarity of geological opportu-*

24. In their account, Bailey *et al.* (1997) use the term 'site' to include also findspots with only one find. Apart from the site in the Voidomatis basin and Kokkinopilos, all other open-air stratified and/or datable sites were discovered during the Nikopolis Project. In the terminology of the Nikopolis Project these are called 'site/scatters' and may include localities with a single find (*e.g.* the biface from Ormos Odysseos). Runnels and van Andel (2003: Appendix) give a list of 36 site/scatters that are 'datable', but it was decided to include here only those sites that were explicitly either reported as yielding stratified artefacts, or considered datable by relative dating (*e.g.* with the use of paleosols) or were actually dated by 'absolute' dating (TL,

IRSL); thus, sites that were dated and/or considered datable on the basis of their typological characteristics are *not* (meant to be) included here. Mesolithic sites are also excluded. Ten more open-air sites, which were discovered during road constructions and yielded Middle and Upper Palaeolithic material, are reported by Palli and Papadea (2004); as this publication was pointed out to me while the thesis was upon completion, these sites have not been included in Tables 4.2 and 4.3

nities for finding sites with material *in situ* and/or datable by geochronological means (for matters of convenience, these are hereafter referred to as ‘S/D’ sites, meaning ‘stratified and/or datable’). Sites that can be regarded as S/D and yielded ‘Lower Palaeolithic’ material represent some 2% of the total number of Palaeolithic sites in Epirus. However, they account for 30% of the open-air S/D sites (3 out of 10), or some 19% of the S/D sites if we include also caves and rockshelters (3 out of 16; Table 4.3). Then, if Lower Palaeolithic material has been recovered in one out of three S/D open-air sites, it appears that wherever there are geological opportunities good enough for S/D sites to be found, there are also good chances that some of those will yield Lower Palaeolithic finds.

Yet, it is extremely difficult to rigidly evaluate whether the above assertion is more apparent than real. Definite conclusions are hindered by the ‘background noise’ generated from an array of interrelated factors: preservation and taphonomic biases (including visibility and accessibility of sites) versus preferences from the part of early humans, and research biases arising from differentially designed survey projects, to name only the most important ones²⁵. Runnels and van Andel (2003) suggested that the strong association of lithic artefacts with redeposited *terra rossa* (‘redbeds’) should be attributed to a combination of preservation issues and the attractiveness of those environments due to the presence of water (and all other resources associated to water bodies)²⁶. In another publication they seem to somehow undermine the preservation factor, when stating that “the

negative results of the searching by survey teams of many areas lying between poljes and loutses reinforces our belief that the association of sites with karstic features is due to prehistoric human behavior and not the result of the chance of preservation or the vagaries of research design” (van Andel and Runnels 2005, 374). Nonetheless, karst depressions do tend to act as sediment traps that collect sediments from the surrounding slopes, concealing and protecting them from erosion, thereby favoring also the burial and preservation of archaeological material; a view that is shared by most scholars that worked in Epirus (*cf.* Runnels and van Andel 2003, 125; Bailey *et al.* 1993; Bailey *et al.* 1997). Similar problems apply to the other side of the coin, namely the evaluation of negative evidence from certain regions. Flysch areas are notable for the absence of sites, and for this conclusion at least research biases can be ruled out, as those areas have been repeatedly surveyed exactly to test that assessment (*ibid.*). In this case the balance between preservation and preference (to put it rather schematically) has been assumed to lean more in favor of the latter factor: certain edaphic properties and the thinness of flysch soils result in an overall low economic potential for the flysch regions, making them unfavorable to animals and hence to humans as well (Bailey *et al.* 1993). The fact that flysch is extremely erodible (*e.g.* Koukis and Ziourkas 1991) is also thought by Bailey *et al.* (1997) to be a factor affecting archaeological visibility and preservation, but, according to the same researchers, this is probably not as decisive as its unattractiveness for human occupation: referring to the erosion of the ‘redbeds’, the latter scholars argue that “indeed, it is this erosion, often producing deeply dissected and dramatic gullies, that has exposed Palaeolithic artefacts and contributed to the visibility of sites[...] We see no obvious reason why this should not have been equally the case of the flysch slopes...” (*ibid.*, 529). However, even if erosion may have been “equally” affecting both types of geological areas (limestone areas with redbeds *vs.* flysch areas), the *mode* of erosion differs substantially in many respects – a fact that has been overlooked in the explanation of Bailey *et al.* (1997). By nature of its structure (sandy layers sandwiched between clayey layers), flysch is mostly eroded through slides and slumps, whilst redbeds are eroded mainly by the action of surface runoff, creep, gully-ing and slope wash. In the former case, slope failures

25. The discussion here focuses more on the role of geological and geomorphological factors affecting site taphonomy and distribution, rather than the differences in any discernible patterns between site distribution in the Middle versus the Upper Palaeolithic, or with regard to open-air sites versus rockshelters/caves. For the latter issues see Bailey *et al.* 1997 and Sturdy *et al.* 1997. Additionally, this discussion involves more the Middle rather than the Upper Palaeolithic evidence, as the former period is more closely related and comparable to the Lower Palaeolithic in all respects (geological formations, behavioral inferences, etc).

26. Note that poljes would have equally attracted other predators apart from humans, and the presence of the former could have rendered these localities dangerous places as ‘residential camps’ for human groups, a fact that is not discussed by van Andel and Runnels (2005).

are more prone to occur, and in a catastrophic and episodic manner (*e.g.* landslides of blocks of sediments), whereas redbeds are more likely to experience a milder type of erosion (*e.g.* debris flows and removal of sediments by gully incision), albeit in a more constant and still vigorous mode. Such differences have hardly been investigated²⁷. Another potential disparity would be with regard to the *onset* and *duration* of erosion in each of the two categories. As discussed earlier, the erosion responsible for the badland-landscape of –for instance– Kokkinopilos was initiated rather late, *i.e.* in the Holocene, and so it can be regarded as a recent phenomenon, namely of relatively short duration. In contrast, erosion of flysch “extends well back into the Pleistocene” (Bailey *et al.* 1993, 301), and this may be responsible for the differential preservation conditions in the flysch areas. Yet, the picture becomes even more blurred if we consider the assertion of Bailey and colleagues (1997, 525) that “the repeated association of [...] artefacts with eroding red sediments in lowland areas of Epirus breaks down when one moves into the Epirus hinterland, where similar deposits are equally extensive but rarely yield flint artefacts”. Unfortunately the researchers provide no other information in support of this observation, which makes it difficult to evaluate it. For instance, in what stage of their evolution do these ‘hinterland-redbeds’ occur? Are they uplifted and dissected similarly to (most of) their lowland counterparts, such as Kokkinopilos, so that they can be comparable in terms of preservation and visibility? Alternatively, do they present evidence of past wet conditions, in order to assess their former attractiveness as wetland environments, as it is stressed by van Andel and Runnels (2005)? A third explanation for the apparent absence of evidence in hinterland-redbeds could involve other constraints, such as behavioral issues related to altitude-thresholds, since the evidence from inland and/or upland

(above 600 m.) areas are overall poor of Middle Palaeolithic evidence as well, irrespective of depositional contexts (Bailey *et al.* 1997).

All the same, the distribution of Palaeolithic open-air sites is patterned very closely to the distribution of karst depressions in limestone areas, whilst sites are rare in other contexts, namely the intervening areas with flysch and flysch-like bedrock, which display clear evidence of intense erosion and disturbance, chiefly attributed to a combination of soft lithologies, reduced vegetation cover and tectonic activity. Although the role of the geological factors has been accounted for in almost all previous investigations, much more needs to be researched in this direction, to elucidate differential site preservation and visibility and test the existing interpretations. What seems to have been largely ignored is how sites like Kokkinopilos may serve as ‘windows of opportunity’ in combining good preservation with adequate visibility. As described earlier, taphonomic observations, such as the fresh to mint condition and the horizontal position in which the artefacts are usually being recovered, together with stratigraphic accounts such as the fine stratification, all point to low-energy depositional processes: altogether, these factors are responsible for a fairly good degree of preservation, which can be attributed to the fact that the artefacts were being discarded on (and subsequently buried in) an essentially *low-gradient terrain*. The raising of the polje by uplift resulted in dissection and exposure of the stratigraphy, which is in turn responsible for a fairly good degree of visibility, too. As mentioned earlier, although erosion may have started already in Palaeolithic times; and notwithstanding differences in the degree of erosion west and east of the main divide, *accelerated* erosion with severe gullying exposing deep sections is in most probability a very recent phenomenon, *i.e.* most likely post-Roman and possibly accentuated after the 1950’s (*cf.* Dakaris *et al.* 1964, 213-214; Harris and Vita-Finzi 1968; Bailey *et al.* 1992, 143). Locally, large parts of the uppermost zone C have already been eroded away, and it can be expected that, at this pace, soon (geologically speaking) the entire deposit will be removed by the gullies into the Louros valley, through a gap in the limestone ridge that serves as the main outflow. However, the point to be stressed is that for a long time the archaeological material has been protected

27. For example, one may add that “flysch basins are unlikely to have supported anything other than sparse open vegetation” (Sturdy *et al.* 1997, 595), in contrast to the redbeds, say of Kokkinopilos, for which Harris and Vita-Finzi (1968, 544) assume that in the absence of anthropogenic disturbance it would have supported a closed cover of mixed oak forest. Qualitative and quantitative differences in vegetation cover would have resulted in differential erosional behavior of the two contrasting landscapes (see also section 6.2).

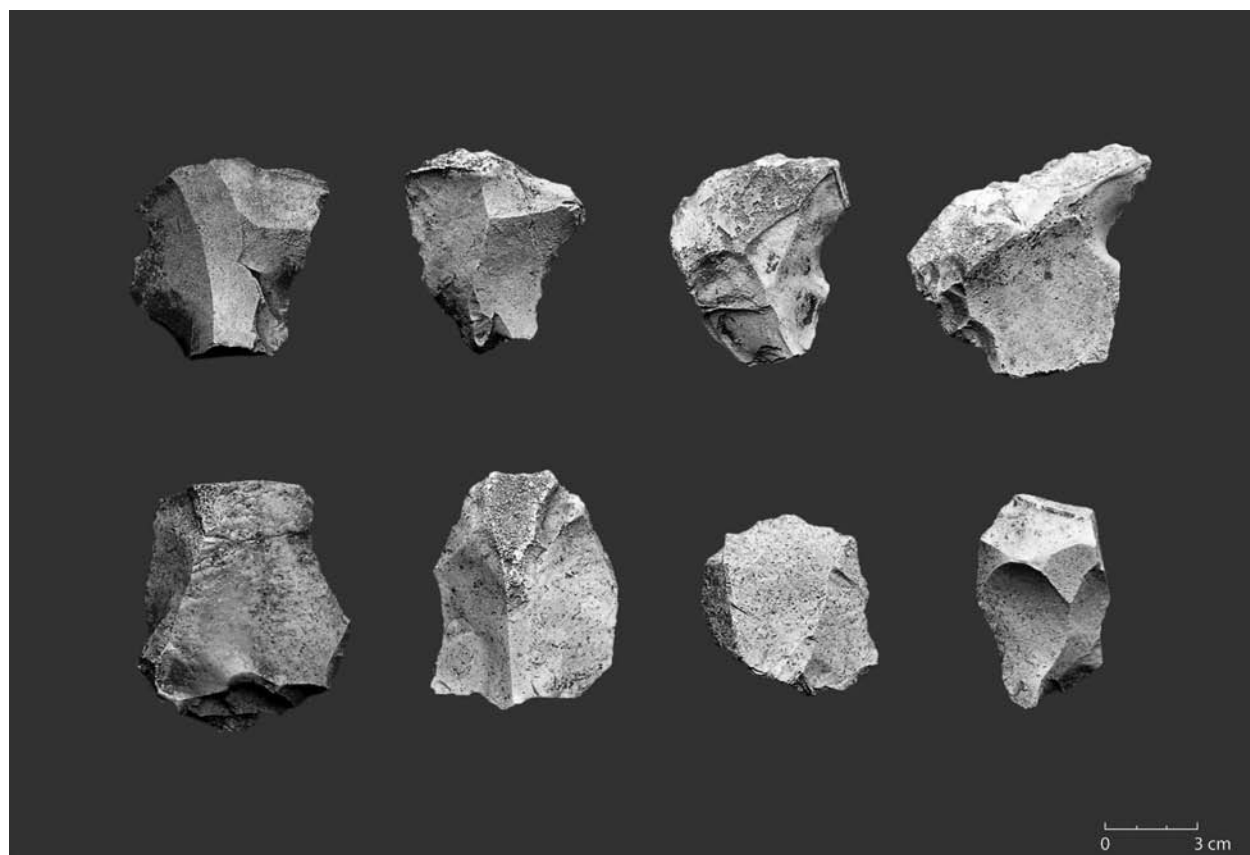


Fig. 4.15 'Chert' artefacts from Alonaki. Lower row: flakes. Upper row: retouched tools (notched pieces and denticulates)

in this closed depression, and luckily for today's archaeologists, the stratigraphy is being exposed only recently; and this is even more true for the lowest (and hence oldest) parts of the sequence. Thus, a 'recently-acquired visibility' is the second factor that makes Kokkinopilos such a valuable 'window of opportunity'. In sum, this would be one of the rare instances where archaeological material has been buried in a flat-floored terrain, remained protected from erosion for thousands of years (either covered by sediments or concealed within paleosols), and it is only lately being uncovered again.

4.5.6 Alonaki

The findspot of Alonaki is situated in the southern part of the Acheron valley (south-western Epirus), at a very close distance from the Ionian Sea and it was discovered during the surveys carried out by the teams of the Nikopolis Project. The depositional set-

ting of the site belongs to an infill of redeposited terra rossa that has accumulated within a karst depression (a 'loutsa'; Runnels and van Andel 2003; see location in Fig. 4.7). In the examined outcrop of the deposits, two distinct Bt paleosol horizons were identified (*ibid.*, 100): the lower has a Maturity Stage (MS) 4/5 or 5, whilst the upper a MS 4. Lithic artefacts (total number: 204, according to Papagianni 2000) were found both on the surface and embedded within the outcrop, as well as in a modern clay extraction pit. The researchers argue that the material belongs to two separate lithic facies, each one associated with one of the two Bt horizons; apart from this stratigraphic distinction, the two industries are thought to be distinguishable on the basis of differences in the raw material and the techno-morphological characteristics of the artefacts (Runnels and van Andel 2003), although both groups are almost uniformly heavily patinated.

Runnels and van Andel (2003, 103) correlate the lower Bt horizon at Alonaki with another (truncated) paleosol horizon displaying similar maturity indicators, which is overlain by a coastal sand dune in a profile exposed *ca.* 500 m to the west of Alonaki, at Ormos Odysseos; the researchers assume that the sand dune dates to either the last interglacial or “an even earlier interglacial”. There, Palaeolithic artefacts and a small handaxe were found on deposits that are thought to be associated with this paleosol horizon. Thus, on the basis of the maturity of the paleosol horizon (the lower Bt) and its stratigraphic position below a sand dune of possible last interglacial age, Runnels and van Andel suggest that the chert artefacts at Alonaki and the biface from Ormos Odysseos most likely pre-date the last interglacial and are older than *ca.* 130 ka, possibly approaching the age estimate for the Kokkinopilos handaxe (*i.e.* 150–250 ka).

At Alonaki, the lower horizon industry, considered to be of Lower/‘Early’ Palaeolithic age, is basically a ‘core-and-flake’ assemblage, consisting of large flakes with wide, thick, unprepared platforms and large bulbs of percussion; large cores on cobbles with wide and deep flake-scars (Fig. 4.16); core-choppers; tools predominated by notched pieces and denticulates with notches formed by the so-called ‘Clactonian technique’; whilst retouch on scrapers is commonly direct and invasive²⁸ (Fig. 4.15). Overall, there are traits pointing to the use of hard-hammer direct percussion, and a knapping sequence oriented mostly in the production of large flakes and flake-tools (Runnels and van Andel 2003). These artefacts are made on a coarse-grained fossiliferous Eocene chert that is generally uncommon in Epirus and as yet of unknown origin. Noteworthy is also the identification of dense concentrations of angular stones (found in association with the artefacts of the lower horizon), which are seen as reminiscent of ‘stone clusters’ recognized at other early sites (*e.g.* Hoxne; Runnels and van Andel 2003, 100).

In contrast to the latter group of lithics, the artefacts associated with the upper Bt horizon have been manufactured on a bluish-grey, nodular fine-grained flint that derives from Mesozoic limestone and was widely used throughout Epirus during the Middle and Upper Palaeolithic. Runnels and van Andel consider these flint pieces as belonging to a “conventional Middle Palaeolithic Mousterian”, and, while stressing the differences with the chert artefacts described above, they note that “in the lower levels of the deposit [*viz.* the lower Bt horizon] wherever in situ artefacts were observed, they were always of the non-Levallois big flake type” (2003, 100–101). Papagianni (2000) carried out a typo-technological analysis of the Alonaki material, examining it also with regard to the division into the coarse-grained chert pieces of the lower horizon versus the fine-grained flint artefacts of Mousterian character from the upper horizon. Her remark (*ibid.* 56) that “radial cores on coarse raw materials [*viz.* chert] were worked with a variety of methods: lineal or recurrent centripetal Levallois and discoid” is in contrast to the assertion of Runnels and van Andel that the chert artefacts are lacking the Levallois method. On the other hand, my own inspection of part of the collected material and the artefacts that I recognized at the site, failed to identify Levallois characteristics on the chert artefacts, and even the ‘flint group’ presents only a few pieces with unequivocal evidence of classic Levallois features *sensu stricto* (*cf.* Boëda 1995). Papagianni concludes that “the only differences between the two raw material groups [...] are that artefacts made on coarse raw materials are larger and have a higher representation of plain, unprepared platforms” (2000, 57). According to Papagianni, the differences between the two groups are most likely a function of raw material properties and a distinction between two lithic facies does not find support on the basis of the typo-technological analysis.

When I examined the site I was not able to identify with certainty the exact outcrop where Runnels and van Andel observed the two paleosol horizons and the associated lithic industries. Most probably, the deposits that were investigated in 1992–1993 have since been so much eroded that, when I visited the site in 2007, there was no vertical exposure for a proper examination of the stratigraphy. Consequently, it was not possible to securely assess the ex-

28. My own observations after inspecting the material stored in the museum of Ioannina generally concur with the descriptions of Runnels and van Andel (2003, 101) and Papagianni (2000, 55–57).

istence of two distinct Bt horizons. Large parts of the exposed deposits seem to preserve an undisturbed stratigraphy, but at a few other places there appears to be either eroded remnants of paleosol horizons or reworked sediments deriving from paleosols that were disturbed by past erosional events. That being said, the deposits still reach a thickness of 2-3 m (hence in accordance with the reported total depth of the sequence); undisturbed occurrences are considerably indurated and display all characteristics of mature Bt horizons as described by Runnels and van Andel (*e.g.* with an angular blocky structure and thick, abundant clay films). The deposits could only be coarsely divided into an upper and a lower stratigraphic level, presumably corresponding to the two reported Bt horizons, but as already stated, this is a tenuous assessment. In accordance with the view of the researchers, coarse-grained lithic material (hereafter ‘chert artefacts’) are almost exclusively associated with the lower levels (lower Bt?), whilst fine-grained material (‘flint artefacts’) are associated with the upper levels (upper Bt?); however, a few flint pieces were found also in the lower levels of the deposit, whereas the opposite situation (chert artefacts in the upper levels) did not seem to occur.

The inspection of the coastal sequence outcropping at Ormos Odysseos did not yield any conclusive results: a paleosol (Bt) horizon was tentatively identified, intercalated between layers of sands and clays in the lower part of the exposure, and overlain by sandy deposits of the sand dune attributed by Runnels and van Andel to the last interglacial; whereas another, less mature horizon appears to occur above the sand dune. Due to permit-constraints it was not possible to systematically clean the section, which would allow for a better examination of the stratigraphy; therefore, it was not feasible to assess the correlation suggested by Runnels and van Andel between the Bt horizon occurring at the lower part of the sequence of Ormos Odysseos with the lower Bt at Alonaki. At first sight, however, such a correlation appears to be most likely valid, supporting an attribution of the lower Bt artefact-yielding horizon at Alonaki to a fossilized palaeo-surface that pre-dates the last interglacial.

Overall, the study of the stratigraphy at Alonaki and the nearby locality of Ormos Odysseos encountered significant difficulties, mainly arising from the fact

that in both places the pedo-sedimentary associations have been considerably disturbed by erosional processes. Moreover, in some instances it was clear that such disturbances were caused by old -rather than recent- erosional episodes: for example, the lower paleosol horizon at Ormos Odysseos appears to have been locally reworked by marine transgression(s). All in all, Runnels and van Andel (2003, 100) explicitly acknowledged these problems, and especially with regard to the Alonaki stratigraphy, for which they state that “[...] our ability to correlate the industries with outcrops of different depths is limited”. In sum, their correlation of the two lithic facies with the two Bt horizons could not be neither falsified nor confidently verified by this recent re-examination, although it is believed here that it most probably holds well, as far as macroscopic observations are concerned.

Nevertheless, even if we accept that the chert artefacts from Alonaki and Ormos Odysseos predate the last interglacial, it is still not possible to securely attribute them to the Lower Palaeolithic, as Papagianni’s analysis also implied. In fact, Runnels and van Andel themselves carefully remark that the ‘chert group’ may equally be seen as belonging to a “late Acheulean technocomplex” or to a “variant of an early Mousterian” (2003, 126). Interestingly, the latter researchers report also that they did not identify any similar artefacts among the material collected in Epirus by E. Higgs (*ibid.*, 105). Indeed, in terms of raw material and typo-technological characteristics, the ‘chert group’ from Alonaki differs from all other Epirote assemblages, of which I personally examined some samples, either in Ioannina or at the sites, while doing fieldwork (*e.g.* from Kokkinopilos, Karvounari, Morphi and Ayia). Papagianni’s study of Middle Palaeolithic technology in Epirus also reveals a number of techno-morphological traits that, in many respects, distinguish this material from that of the rest of the Epirote sites (2000, 55-57), when the former is viewed as one unit (*i.e.* chert and flint ‘groups’ together): for example, the Alonaki collection has the highest frequency of cores among the sites studied by Papagianni, and the lowest frequency of elongated flakes and tools in all coastal sites of Epirus (with specimens with blade proportions being particularly rare); very few prepared platforms (occurring mostly in the ‘flint group’); highest frequency of notched

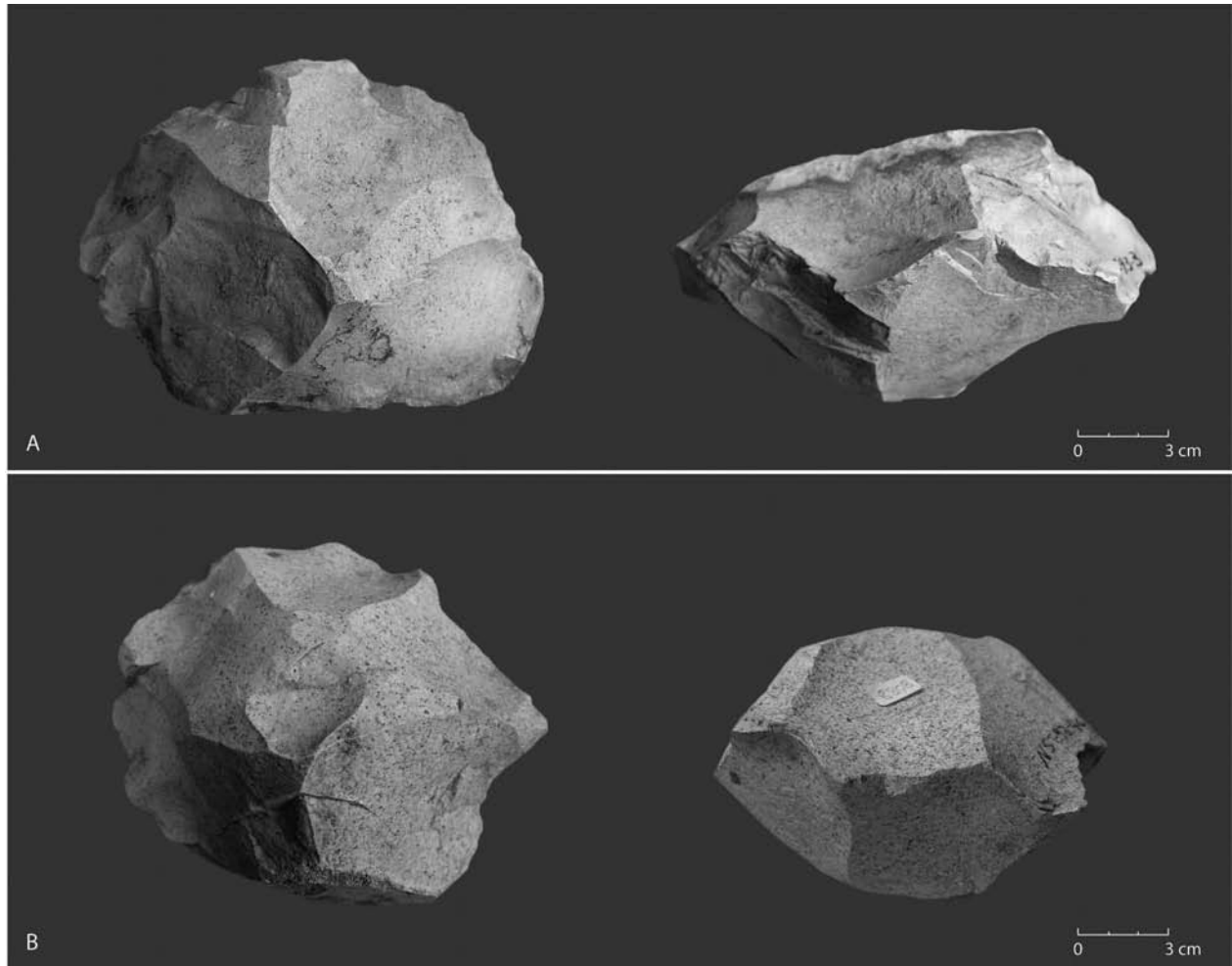


Fig. 4.16 Cores of the 'chert group' from Alonaki. A: disc-like core. B: discoidal (?) core

pieces and denticulates and highest frequency of re-touch invasiveness in all coastal sites of Epirus; and highest number of large artefacts.

As already discussed in section 2.1, although core reduction techniques are a primary study-focus for distinguishing between Levallois and non-Levallois (or, in this context, 'pre-Mousterian') assemblages, such a distinction remains provisional if it relies solely on core properties. Nevertheless, the interpretation of core technology is critical in the case of the 'chert group' from Alonaki, since Levallois features are either missing or doubtful for the rest of the coarse-grained artefacts. Some of the cores and 'core-choppers' that I examined in the Ioannina museum and at the site would be described as 'migrating platform

cores' reduced by alternate flaking, which point to a reduction strategy wherein flakes are removed in an invasive fashion from the volume, rather than the surface of the core, and in a non-standardized manner (*cf.* White and Ashton 2003). Yet, next to the latter are cores which could be described as 'simple prepared cores' and/or discoidal (*e.g.* the latter term is used also in Papagianni 2000, 56); these are generally flatter (in contrast to the chunky appearance of the former type) and seem to indicate a better control on flaking (Fig. 4.16). Considering, however, that this is essentially a surface material lacking refits, and most likely biased by not only collection strategies but also by a degree of post-depositional mixing (*cf.* Papagianni 2000), such remarks should be taken with caution. Furthermore, methods of core reduc-

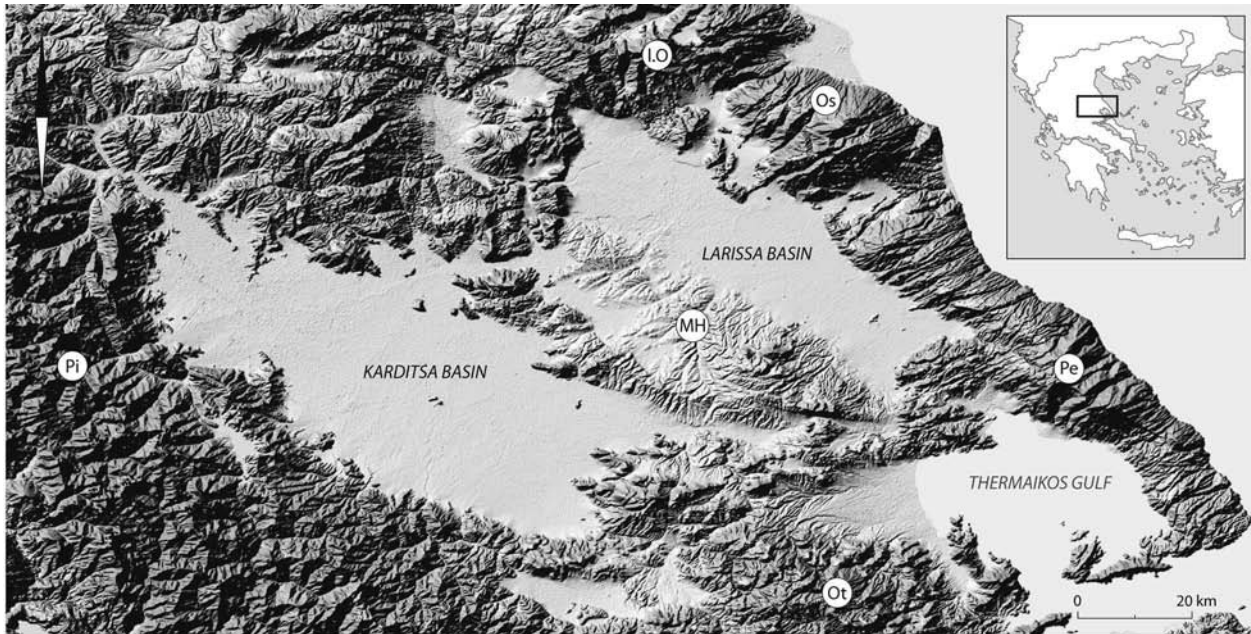


Fig. 4.17 Relief map of Thessaly, based on data from SRTM v.2.0. Pi: Pindus Mountains; I.O: Mt. Lower Olympus; Os: Mt. Ossa; Pe: Mt. Pelion; Ot: Mt. Othrys; MH: Middle (Thessalian) Hills

tion can change while the core is being knapped, and so its final form reveals only the last method applied (*e.g.* Kuhn 1995). Even more important for the case of Alonaki are the constraints imposed by the properties of the raw material, as Papagianni discusses also in more detail (*ibid*; see also Dibble 1991; Kuhn 1991, 1995; Andrefsky 2008). Notwithstanding all the above, the geometry of the two main types of cores described earlier can be seen as indicative of a technological tradition which could be attributed to the transition from the Lower to the Middle Palaeolithic. Needless to say, the issues related to the raw material, the small size of the assemblage, and the fact that it consists of surface finds, renders any such attribution highly hypothetical; following Papagianni, there are no clear-cut differences in the technology of knapping between the ‘chert’ and the ‘flint group’, and both could belong to a ‘Mousterian tradition’ even if they are indeed separated in time, as the stratigraphy seems to suggest. On the other hand, it has already been noted (sections 2.1 and 3.3) that, for instance, discoid cores have been documented at sites as old as the ones at Orce, whilst the latest analysis of the Dmanisi lithic material remarks on the presence of cores, which typologically and/or volumetrically could be considered as discoid.

Noteworthy, at the peninsula of Ayios Thomas (see Fig. 4.7 for location), large flakes and an amygdaloid biface or bifacial core made on chert similar to that used at Alonaki, were collected from a paleosol that is associated with marine deposits of Eemian age (Runnels and van Andel 2003). These, too, could be tentatively attributed to a late Lower Palaeolithic or an early (?) Mousterian industry, or to a technocomplex that is transitional between these two.

In sum, at Alonaki, it was not possible to neither confirm nor falsify an attribution of the material to the Lower Palaeolithic. What is observable is that the ‘chert group’ displays characteristics that distinguish it from the known Mousterian assemblages of Epirus and lacks any traits indicative of a ‘post-Mousterian’ period. Although the Alonaki material clearly belongs to a core-and-flake industry, bifaces are not absent from the immediate surroundings (Ormos Odysseos), or from the wider area (Ayios Thomas, Kokkinopilos).

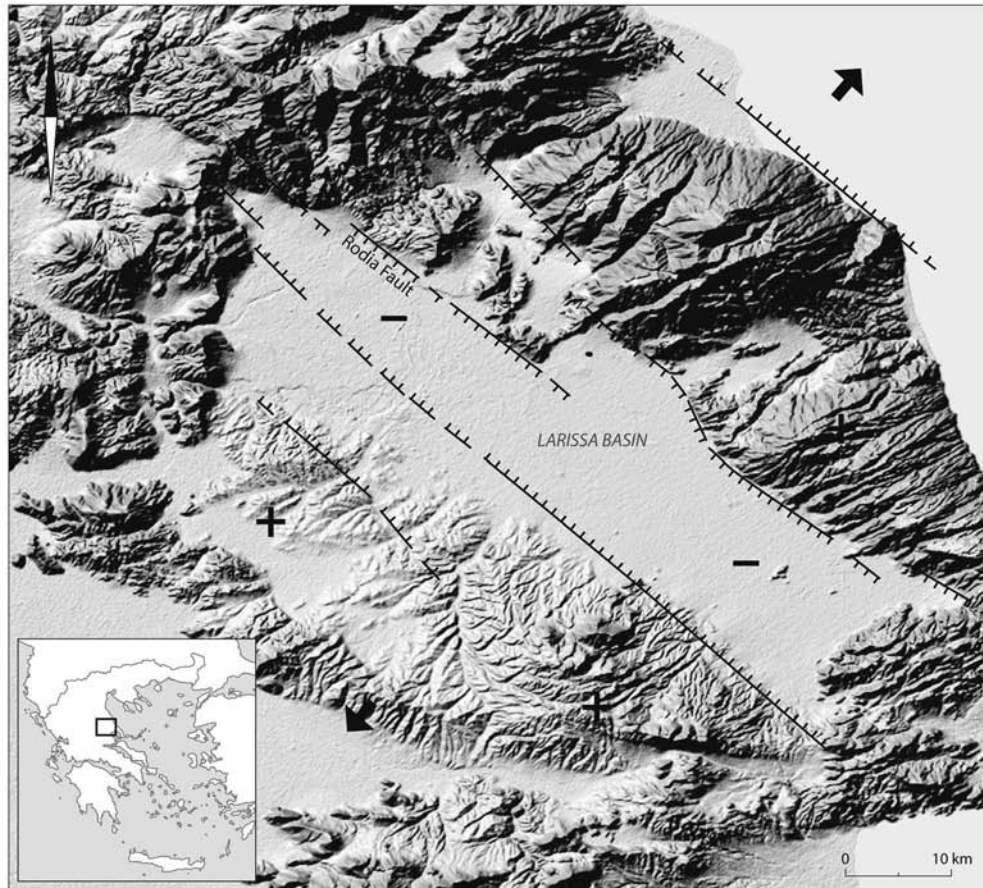


Fig. 4.18 Pliocene-Early Pleistocene extensional regime (first tectonic phase). Arrows indicate the direction of crustal extension, plus and minus signs indicate uplift and subsidence, respectively. Note the Rodia Fault cutting across the entrance of the Narrows. Modified after Caputo *et al.* 1994: fig. 2

4.6 THESSALY

4.6.1 Introduction

The province of Thessaly lies in central Greece and is the largest lowland region of the Greek peninsula (Fig. 4.17). With the Larissa Plain being the most significant geomorphological feature, the area hosts wide plains and meandering rivers, surrounded by high mountains. To the east, the ranges of Mt. Olympus, Mt. Ossa and Mt. Pelion form an almost continuous chain, whereas the region is bordered to the west by the Pindus mountain chain and to the south by Mt. Othrys. The Pineios River has its headwaters in the Pindus, from where it runs south, then east and northeast to pass through the Vale of Tempe between Mt. Olympus and Mt. Ossa and meet the sea of Ther-

maikos Gulf. At least from the Middle Pleistocene onwards, the Pineios has been the primary source of drainage, forming extensive alluvial plains mostly at the central and eastern part of Thessaly. The NW-SE trending 'Middle Thessalian Hills' divide the region into the plain of Larissa in the east and the plain of Karditsa in the west, whereas two smaller basins, those of Almyros and Volos, are to be found further southeast.

The rich alluvium, deposited by streams from the surrounding mountains, and the vast, low-relief floodplains of Pineios and its tributaries (*e.g.* Titarisios River), have been acknowledged for their fertility already from the Neolithic period. Indeed, some of the most important Neolithic settlements of Greece are situated on the Thessalian plains, and the

first Palaeolithic investigations of the region were conducted in the frameworks of projects that were primarily concerned with research on Neolithic sites. The point to be stressed is that, if not from the Neolithic onwards, the plains of Thessaly are in modern times being intensively exploited for agricultural purposes, with considerable implications for the preservation –and hence visibility– of (Lower) Palaeolithic material. In fact, it is possible that even the Neolithic land use may have affected the rate of aggradation – as well as its spatial distribution– during the latest recorded episode of alluviation (*ca.* 7000 BP), through cultivation, deforestation and pasturage (van Andel *et al.* 1990a; Demitrac 1986).

4.6.2 Geology and geomorphology of Thessaly

Most of the substratum of Thessaly (*i.e.* the Alpidic and pre-Alpidic series) belongs –from east to west– to the Pelagonian, Sub-Pelagonian and Pindos isopic zones (Higgins and Higgins 1996). The Pelagonian zone consists mainly of shallow-water limestones and is at present exposed in the northern and eastern parts of the region, from the Pagasitikos Gulf up to the north-west past Mt. Olympus. The Sub-Pelagonian zone runs from Mt. Orthrys to the north of the Karditsa basin and it forms a large belt of ophiolites, limestones and cherts. A deep, continental trough that continues northwards into Albania was developed during the Oligocene and Miocene, when compression changed to extension. Molassic sediments (conglomerates, sandstones and marls) were shed from the adjacent mountains to fill this trough, which is the largest molassic basin in the Greek peninsula (known also as Meso-hellenic Trench; Higgins and Higgins 1996).

After the Alpidic orogenesis, Thessaly was affected by extensional tectonic movements (Caputo and Pavlides 1993). This is the first phase of Neogene stretching affecting the region and it is chronologically bracketed between the Late Miocene/Pliocene and Early Pleistocene (*ibid.*). During this tectonic regime (Fig. 4.18), NE-SW tension resulted in the formation of a series of NW-SE elongated horsts and grabens, bounded by large normal faults that run parallel to the boundaries of the isopic zones (Caputo *et al.* 1994). The Larissa Basin, the dominant geomorphological feature of Thessaly, essentially corre-

sponding to the present Larissa Plain, is formed during this phase, when the structural system of the entire region is being shaped in the form of a range-and-plain topography, with its ‘highs’ and ‘lows’: from east to west, we find the crustal blocks of Olympus-Ossa-Pelion Range, and then the basin of Larissa, separated from the Karditsa Basin by the horst of the Middle Thessalian Hills. Sedimentary conditions were affected by the uplift and subsidence of the aforementioned structural highs and tectonic depressions, respectively. Specifically, during the Pliocene and until the end of the Villafranchian²⁹, the palaeogeography of the region is marked by prevailing lacustrine conditions, when a large lake was covering most of eastern Thessaly (*i.e.* the entire Larissa Basin and most of the Middle Thessalian Hills; Fig. 4.18). At around the end of the Villafranchian, a new drainage pattern emerges, as the Pineios river began to form its delta at the Aegean coast, along with the opening of the Vale of Tempe across the mountains of Ossa and Olympus; consequently, the Pliocene lake occupying the Larissa Basin began to empty (Caputo *et al.* 1994, 220).

The second extensional tectonic activity, this time with an N-S stretching direction, started during the Middle-Late Pleistocene and it continues up to the present (Fig. 4.19). Within these new geodynamic conditions, some of the older, Pliocene normal faults were reactivated, whilst a new system of E-W trending normal faults was being formed and imposed onto the older structures, inherited from the earlier tectonic phase (Caputo and Pavlides 1993, 354). A significant change in the palaeogeography of the region occurs during this phase, as the Larissa basin is now being fragmented into three separate physiographic domains: the Tyrnavos Basin to the north, which coincides with the alluvial plain of the Pineios and Titarissios rivers, the Karla lake to the south, and the Chasambali bulge in between, which forms a system of northwards down-stepping normal faults that impose a temporary hydrographic divide between the other two main sectors (Caputo *et al.* 1994). This recent ‘breaking-up’ of the Thessalian

29. The term is retained here as it is used by Caputo and colleagues (1994), who originally assessed the chronological bracketing of the main tectonic phases affecting Thessaly.

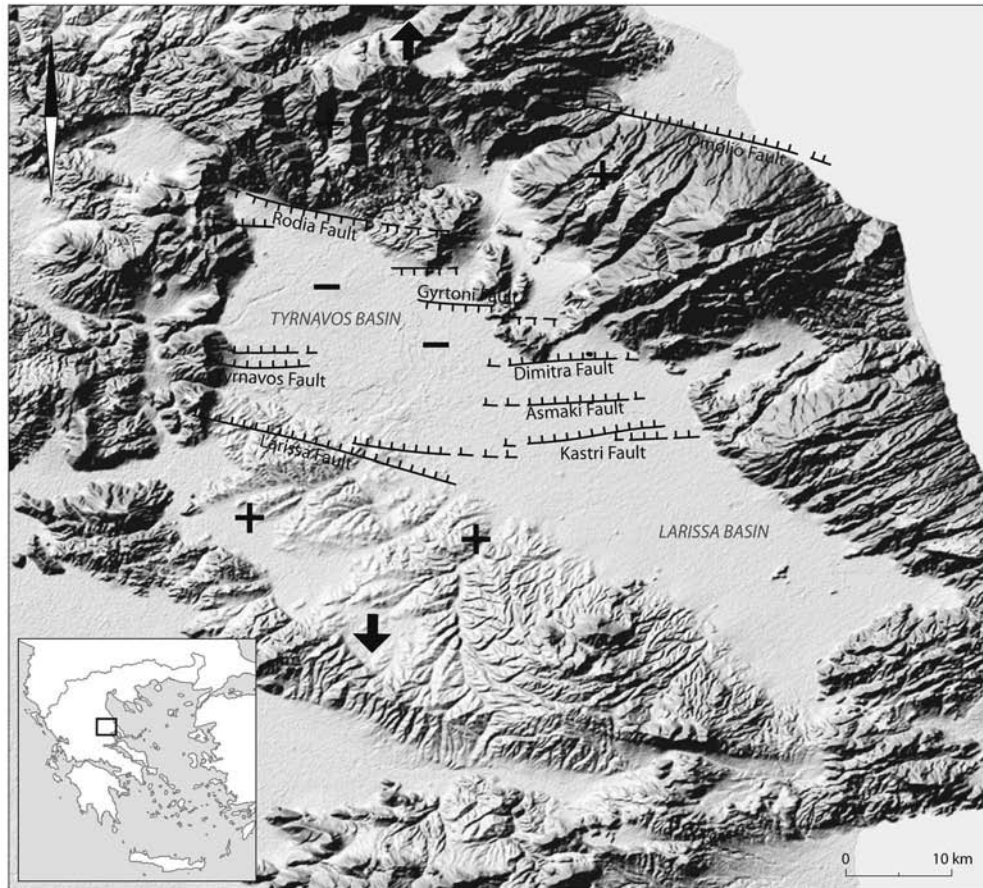


Fig. 4.19 Middle Pleistocene to Holocene extensional regime (second tectonic phase). Modified after Caputo *et al.* 1994: fig. 4

system was accentuated by a new uplift of the Gonoï Horst (that is, practically the south-western parts of Lower Olympus and Ossa) and the northern part of the Middle Thessalian Hills, along with a continuous subsidence of the Tyrnavos Basin (*ibid*). It is stressed here because it had significant implications for the distribution and preservation of the Quaternary sediments: whereas from the Middle-Late Pleistocene onwards the Tyrnavos Basin was strongly subsiding, thereby forming a significant sediment trap, the northern parts of the Middle Thessalian Hills were being uplifted, whilst the area south of the Larissa Fault remained almost undeformed.

4.6.3 Previous research and interpretations

Palaeolithic research in Thessaly was initiated in 1958 by a German team under the direction of V. Miložčić and it was the outcome of those investigations that gave way to the publication of the first monograph on a Greek Palaeolithic project (Miložčić *et al.* 1965). The researchers surveyed along the banks of Pineios from the town of Larissa up to the village of Amygdalia (previously known as Gounitsa), and located twenty open-air sites with lithic and faunal material. The sites were studied and interpreted on the basis of the typological characteristics of the *ca.* 600 flint artefacts, the faunal analysis and the geological stratigraphy. At three sites, flints and bones were found *in situ*, embedded in the profiles, and their archaeological layers were used as anchor points for relative chronostratigraphic subdivisions and inter-

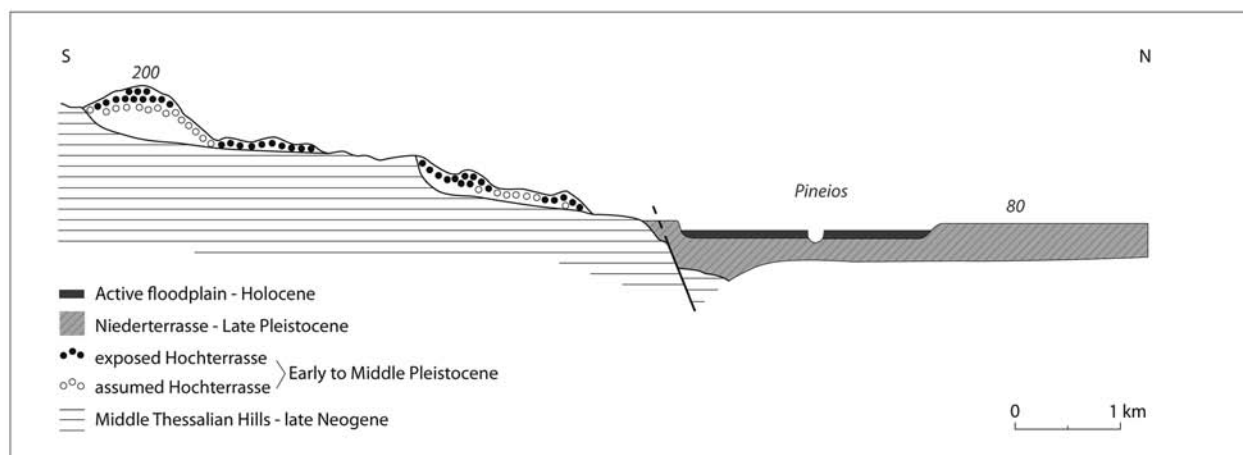


Fig. 4.20 The fluvial sequence in Thessaly as documented by Schneider (1968: Table 4)

site lithostratigraphic correlations³⁰. Nevertheless, most of the artefacts were found on the surface of fluvial deposits that were interpreted mainly as remnants of old (inactive) gravel bars, whilst lacustrine facies and deltaic deposits were invoked for layers with clays and molluscs, and coarse sands and gravels respectively. The researchers assumed that the finds were being exposed and then eroded away by the Pineios at times of excessive discharge when the river's level is rising. Most of the surface finds lacked any traces of rolling and they were usually to be found at the exits of river loops, whereas they were in turn missing further downstream; hence the investigators concluded that -in their majority- they derive from artefact-rich layers that are broached by the river at periods of high water level (*e.g.* in spring and autumn). Interestingly, a bone-rich layer which at site I yielded also numerous flint artefacts could be identified at other localities (*i.e.* at site V and profile 6/7) located more than 3 km away. Both the faunal and the lithic material from this 'bone-layer' ("Knochenbank" in the publication) lacked any traces of rolling or reworking. Consequently, the researchers considered the (stratified) finds as being geologically *in situ*, *i.e.* of the same age with the sedimentary matrix: "Transport over short distances, relocation within a gravel-surface and thus a dispersion of the remainders of a skeleton or of tools over a more or less

expanded range before the final embedding are quite possible, but without any disturbance of the synchronicity between sediments and fossils" (Milojčić *et al.* 1965, 15, translated from German).

D. Jung and H. Schneider, the geologists of the German survey team, were the first who studied in a relative detail the Thessalian fluvial stratigraphical sequence. As discussed below, the geological examination deduced a broad subdivision of the stratigraphy into four fluvial terraces (fig. 4.20; Milojčić *et al.* 1965, 8-20; Schneider 1968). The *Hochterrasse* ('high terrace') is the oldest, presumably spanning the Early to Middle Pleistocene and it can be further subdivided into a *lower* and an *upper* unit. The next terrace is the *Niederterrasse* ('low terrace'), formed by three successive alluvial episodes during the Late Pleistocene to Middle Holocene; almost all of the findspots discovered during this first phase of research were proved to be associated with the *Niederterrasse*. The fourth and youngest terrace is formed by the modern, active floodplain of the Pineios.

The results of the faunal analysis indicated a 'warm type' of fauna from the sites associated with the *Niederterrasse*, and this fauna was considered to date from the Last Interglacial up to the beginning of the Last Glacial (Milojčić *et al.* 1965, 58). This view, and particularly the presumed occurrence of Last Interglacial taxa, was later further elaborated by Schneider, also based on the presence of molluscs and lignite layers, which he considered indicative of

30. Theocharis (1967, 18-19) reports that there was only one site with *in situ* artefacts (site 7).

temperate climatic conditions, although he acknowledged the ambiguities in these conclusions³¹ (Schneider 1968, 31-35 and 37-42). Schneider's excellent study on the geological evolution of the Thessalian landscapes established a relative chronological framework for the fluvial sequence and offered insightful observations on the links between tectonics and climate as driving forces behind river behavior and related sedimentary environments.

A few more findspots were discovered in 1960 by the Greek archaeologist D. Theocharis, who surveyed essentially the same part of the river valley, adding more than 250 lithic artefacts to the total collection, as well as an unspecified number of fossil bones (Theocharis 1967, 20). Noteworthy is the recovery of a human calvaria fragment, found in site E (at the northern bank of Pineios, close to Larissa town) embedded in a sandy layer *ca.* 3.5 m under the surface of the river bank. Three flint tools³² were found in the same layer, but they were recovered "from different parts of the layer" and their association with the skull fragment is dubious (*ibid.*, 32-33). J. L. Angel, the anthropologist who examined the fossil in 1965, concluded that it "does not look like a Neanderthal in the classical sense of the term", and that some of its features are reminiscent of the specimens from Swanscombe and Krapina (*ibid.*, 33). Perhaps even more remarkable than the find itself is the fact that, apart from a very brief reference by G. Freund (1971, 183), the human fragment seems to have been not only unexamined, but also unnoticed in the literature since Theocharis' publication in 1967. In their analysis of the lithic material, both Milošević and Theocharis assigned a Middle Palaeolithic age to the majority of the collection, and argued for the existence of an Upper Palaeolithic component as well, albeit with a weaker 'signal'. Following Freund (1971, 186), the identification of a Middle and -most

probably- also an Upper Palaeolithic constituent in the collection is by no means doubtful, but the secure stratigraphic points are seemingly too few to allow for a solid chronological assessment of the surface material. This regards mainly the identification of a 'younger' Middle Palaeolithic facies and perhaps also the argumentation for a stratigraphic position of the Upper Palaeolithic component. The stratified artefacts in 'zone a' (*i.e.* the stratigraphical anchor for the Upper Palaeolithic occurrences) were no more than six pieces, which, according to Freund (1971, 186), could be Upper, late Upper Palaeolithic "or even younger". Furthermore, aside from the few sites with embedded lithics, almost all of the localities yielded assemblages in which 'Middle Palaeolithic' artefacts are found mixed with 'Upper Palaeolithic' pieces, if not also with specimens that probably belong to the Bronze Age (as in site 0). In fact, Freund's assertion that "*de facto* ist das saemtliche Material verlagert, auch das stratigraphisch gesichert"³³ (1971, 194) draws our attention not only to the deduced culture-specific classification of the total collection, but perhaps also to the very same stratigraphic correlations that presumably permitted this sort of classification.

Overall, it seems that during these two first expeditions in Thessaly the investigators aimed primarily at the bank exposures of Pineios, whereas the higher terraces (the 'Hochterrasse') were visited chiefly for geological reconnaissance purposes and were not thoroughly scanned for artefacts. However, the geologists mention the presence of "atypical" (*sic*) lithic artefacts on the surfaces of the *lower Hochterrasse*, which were found "always lying loose on the surface and never in situ" (Milošević *et al.* 1965, 17; Freund 1971, 194). Although Schneider was apparently familiar with recognizing flint artefacts, in his 1968 publication there is no report on any find from the Hochterrasse, which he assumingly investigated thoroughly in order to map it. The Middle and Upper Palaeolithic specimens are made on radiolarite, ranging in colours from ochre (rarely) to red-brown (the majority) and dark red; raw material occurrences were readily available in the form of fluvial gravels

31. "The molluscs found in the layers of the 'Knochenbank' give little hope for a more precise dating. As a whole, they represent a Pleistocene-Holocene fauna without a high stratigraphical value, but they point to an interglacial age" (*ibid.*).

32. Drawings of two of the three lithic implements are presented in the publication and, in accordance with the interpretation of Theocharis, these appear to be a discoidal (Middle Palaeolithic?) core and a burin (Theocharis 1967, Fig. 1, 3 and 22, 1).

33. "All of the material is *de facto* relocated ["derived"], also that which is stratigraphically secured."

on and within the Hochterrasse deposits a few kilometers away from the findspots (Schneider 1968, 38). Noteworthy is a point made on quartz, which is included in the material collected by Theocharis (Freund 1971, 189), and is so far the only reported quartz-artefact from a (presumably) Late Pleistocene context: as it is discussed later, the 'Lower Palaeolithic' assemblage from Rodia is made on quartz, and this is contrasted to the raw material of the Middle and Upper Palaeolithic specimens which are worked exclusively on radiolarite.

During the next phase of Palaeolithic research in Thessaly in the mid 1980's and early 1990's, new search strategies were being applied for the identification and interpretation of open-air Quaternary archaeology (Runnels 2003a). Thus, when in 1987 C. Runnels undertook a survey in the Larissa district with the aim of clarifying the Greek Middle Palaeolithic framework, the targeted areas included locations and landscape features that were deemed promising for yielding finds, based on the geological maps that A. Demitrack had prepared (Runnels 1988, 278; Demitrack 1986). Demitrack's soil-stratigraphic study of the Late Pleistocene Larissa Plain coincided with an increasing understanding of soil chronosequences and their value in dating open-air sites (e.g. Pope *et al.* 1984), the latter gradually gaining appreciation in research designs, as the archaeological paradigm started to shift away from the long-persistent focus in caves and rockshelters (Runnels 2003a, 189).

Runnels revisited some of the known findspots and discovered thirty-two new ones, producing a collection of 211 flint artefacts, which he attributed to the Middle and Upper Palaeolithic (Runnels 1988). For the dating of the material Runnels used the radiocarbon and Uranium-series dates obtained by Demitrack (1986) on molluscs and pedogenic carbonates, which bracket the deposition of the associated (Niederterrasse) deposits between *ca.* 45-27 Ka (Runnels 1988, 283-284). The specimens were found "on the gravel bars in the Pineios riverbed or on the fossil terraces [*i.e.* the Niederterrasse] preserved in the river gorges west and north of Larissa at a height of *ca.* 15-40 m above the present river" and "some [of the findspots] could be correlated with the stratification visible in the river banks of the lowest terrace of the river"

(*ibid.*, 279). There is only one findspot (No. 17) for which flints (of Upper Palaeolithic morphology) are reported to have been recovered from a conglomerate layer (*ibid.*, 283). Otherwise, the artefacts are again surface finds, considered to be deriving from conglomerates exposed in the river banks, assuming little transport of low velocity based on artefact-preservation conditions (Runnels 1988, 280). With regard to "the position of the lithic-bearing deposits within the fluvial sequence", it is implied that this should be correlative with the stratigraphic position of the *in situ* material found by Milojević at *ca.* 6-9 m below the surface (*ibid.*, 283), which essentially refers to the 'bone-layer' ("Knochenbank"); conglomerate adhering to the surface of bones and flints found in 1987, as well as the fact that there are no rolling traces, come in support of this argument. It is worth noting here that the "Knochenbank", this artifact-yielding layer of conglomerates was the main paradigm to claim that probably most of the surface material derives from similar (if not, in cases, the same) conglomeratic layers, a view that was supported and elaborated by Schneider as well: consolidation of the sediments through a carbonate-rich matrix preserved artefacts and fossils, until the erosive power of Pineios recently exposed the layer(s) on the banks of the river (Milojević *et al.* 1965; Schneider 1968, 42).

In addition to the surveys along the Pineios river in the Larissa district, the 1987 survey included eleven other areas with Pleistocene alluvial fans, focusing on relict alluvial paleosols (Runnels 1988, 278). Although nothing is reported from these investigations, a findspot was located to the northeast of Larissa and close to the village of Rodia, at the point where the river enters the Rodia Narrows, which is the gorge that connects the eastern Thessalian plain with the Vale of Tempe. Overlooking the entrance to the gorge and situated on a gravel terrace, Findspot 30 (FS 30) yielded artefacts of Middle and Upper Palaeolithic morphology made on radiolarite. 'Tested pieces' (radiolarite pebbles with two or three flake removals) were included in the finds and hence the site was interpreted as an 'atelier' that could have been revisited in many periods for flint acquisition and testing (Runnels 1988, 282-283). The site was revisited in 1989, and again in 1991, when C. Runnels and Tj. van Andel (1993b) carried out one last survey in Thessaly with the aim of clarifying the geo-

logical context of the Middle Palaeolithic sites and search for Lower Palaeolithic findspots, as well as re-inspecting FS 30 at Rodia. The revisit of FS 30 resulted in the finding of a new lithic assemblage, markedly different from the collection of 1987: instead of radiolarite, these artefacts are made on massive white quartz; they display different technological attributes (*e.g.* the Levallois technique is absent here, in contrast to the previously recovered radiolarite material); and there were specimens found embedded *in* the terrace-profile, a fact which distinguishes their provenance from the radiolarite pieces which were found lying *on* the terrace gravels and in a different part of the site (Runnels 2004, pers. comm.).

Runnels and van Andel employed Schneider's scheme for the Thessalian fluvial succession, noting, however, that his lithostratigraphic subdivisions of the Niederterrasse "are not entirely convincing" (1993b, 299). Aided obviously by Demitrack's (1986) soil maps and descriptions, they interpreted Schneider's "Kalkkrusten" (calcrete) and "brown loams" -identified either within or capping the Niederterrasse deposits- as the Bca / K and Bt horizons of *paleosols*, respectively. In this line, Runnels and van Andel postulate that high interfluvies, submerged only at high flood stages, may have provided surfaces stable enough for soils to grow and humans to use as seasonal hunting camps or kill sites, discarding their artefacts on top of the loam, which would be later washed away by channel migration, thus "leaving the artefacts...in situ on the underlying harder surface of the Bca horizon or even on the gravel" (1993b, 303). Alternatively, artefacts may have been discarded directly on gravel bars, which were exposed at times of low water-level, thereby offering attractive locations for short-term sites and/or hunting stands (*ibid.*). Evidently, this interpretation is somehow contrasted to that of Milojević and his associates. The latter assumed that the finds have most probably been re-located from their original places of discard (and therefore implying a certain degree of reworking; *e.g.* see Freund 1971, 187) but the absence of rolling traces and the crusts of matrix that was still adhering to their surfaces indicate little transport and, most importantly, that artefacts and fossils belong to the same time-slice with that represented by the sediments.

4.6.4 Revisiting Thessaly: fieldwork results

During 2007 and 2008 I visited Thessaly four times, in order to assess the fluvial stratigraphy and the context of site FS30 at Rodia. In three of these visits, I was accompanied by Dr. P. Karkanas, Prof. Dr. R. Caputo and Prof. Dr. W. Roebroeks, respectively; the above scholars offered me invaluable help and thoughtful insights while doing fieldwork, yet any mistakes here are entirely my own. Before presenting the results from the revisits, I will first summarize the main points that the reader needs to bear in mind with regard to the Quaternary in this region.

The Quaternary in Thessaly is essentially represented by the fluvial terraces of the Pineios and its tributaries and to a lesser degree by other landforms of alluvial deposits, such as alluvial fans. Moreover, a small percentage of Pleistocene sediments occur also as fillings of fissures in the limestone and marble bedrock, which often preserve faunal remains. Besides the modern, active floodplain of the Pineios, there are two prominent terraces that mark the Thessalian landscape (Fig. 4.20), and these have been designated by Schneider as the 'Niederterrasse' and the 'Hochterrasse' (Schneider's (1968) nomenclature in German is retained here for convenience). The younger terrace, the Niederterrasse, was active through the Late Pleistocene and early Holocene and currently covers more than half of the floodplain north of Larissa, *i.e.* most of the Tyrnavos Basin. It lies *ca.* 5 to 15 m. above the present, active floodplain and its stratigraphy reveals well-bedded, well-sorted gravels, sands, silts and clays (App. II: 1), which belong to three separate fills, from older to younger (Demitrack 1986):

1. The *Agia Sofia alluvium* accumulated during *ca.* 42 to 27 ka, it is the most extensively aerially exposed Niederterrasse-fill and contains findspots with Middle and Upper Palaeolithic material.
2. The *Mikrolithos alluvium* was deposited between *ca.* 14 to 10 ka, it is always found buried under a younger fill and its deposition is considered to reflect the climatic shift from the late Glacial to post-Glacial conditions.
3. The *Girtoni alluvium* was laid down during *ca.* 7-6 ka, it now covers entirely the Mikrolithos alluvium as well as part of the Agia Sofia; Middle

and Late Neolithic settlements were founded upon it, during and after its deposition.

Late Pleistocene deposits occur also as alluvial fans ('Old' and 'New Red Fan') which are found in a narrow zone, parallel to the mountain front that borders the plain to the east and north (Demitrack 1986; Fig. 4.21). The fans are poorly preserved, and it is only their proximal parts that remain at the surface and always on the up-thrown blocks of faults that cut across them. Episodes of deposition were interrupted by long periods of soil formation, as it can be envisaged by the occurrence of paleosols within the fans. Evidence of two episodes of faulting is also visible in those fans.

Assessing the relative and absolute dating of the Hochterrasse sediments

The Early Pleistocene sediments are patchily found as relict deposits of the Hochterrasse, mainly overlying the Late Miocene-Pliocene sediments of the Middle Thessalian Hills, which separate the basin of Larissa to the east from the basin of Karditsa to the west, and belong to the depositional environment of the palaeo-lake (Fig. 4.21; App. II: 2). Due to the general scarcity of faunal material and lack of dating projects, the age of the Hochterrasse is furnished in the broadest of terms. Possible age estimates are further complicated by the difficulty in identifying a precise litho- and chronostratigraphic boundary between the Late Miocene-Pliocene sediments and the overlying Pleistocene gravels. The palaeo-lake is thought to have persisted until around the end of the Villafranchian; at about that time, the depositional environment changed from (predominantly) lacustrine to fluvial-terrestrial conditions, when Pineios began to establish the new hydrographic system. However, this shift was probably gradual and, consequently, there are sedimentary facies which reflect these boundary-conditions, hence characterized as fluvio-lacustrine. Schneider (1968, 15) comments that in all previous geological works which include Thessaly, the Neogene is referred as 'undivided', and even in the most classic studies, such as that of Philippson (1950), both the Pliocene and Quaternary deposits are left without any further subdivision and/or dating. Importantly, he also stresses that the Quaternary deposits share many affinities with those of the Plio-

cene in terms of their lithographic components (clay, loam, sand, gravels), whereas both the Quaternary and the earlier sediments are associated in their distribution and have both experienced comparable displacements due to tectonic movements (ibid). Nonetheless, Schneider (ibid, 17) attempted a gross subdivision of the Neogene deposits into two parts, based on differences in the stratification, colour, petrography, and tectonic deformation. The *lower thessalian layers* comprise of light-coloured, sandy conglomeratic fluvial-lacustrine sediments that are attributed to the Late Miocene-Early Pliocene based on the presence of a 'Pikermi fauna'. The *upper thessalian layers* consist of fluvial-terrestrial loamy 'red-beds' that are seen as re-worked and eroded remnants of paleosols; for them, Schneider assumes a Plio-Pleistocene age (*sensu lato* Villafranchian), as they are capped by the Early Pleistocene fluvial gravels of the Pineios. It is though obvious that this chronological subdivision does not resolve the problem: the upper parts of what is considered to be the 'Neogene deposits' are thought to span the Plio-Pleistocene boundary, whilst the overlying fluvial gravels of the Pineios are also assigned an age under the term 'Villafranchian' (*i.e.* again Plio-Pleistocene). This is nonetheless partly understandable, since the Pleistocene overall seems to be in stratigraphic continuity with the underlying, Pliocene sediments (Caputo and Pavlides 1993).

Apart from (litho)stratigraphic indications based on the fluvial sequence, the attribution of the Hochterrasse to the Early-early Middle Pleistocene is thought to be supported by a fragment of an elephant molar (M²) that Schneider (1968, 25) assigned to the species *Archidiskodon (Elephas) meridionalis cf. cromerensis* (this species is referred to as *Mammuthus meridionalis* in current nomenclature). The tooth was found before World War I by an amateur, who in 1968 showed Schneider the exact location of the find, some 1.5 km south of Larissa at *ca.* 90-100 m. asl on the Middle Thessalian Hills; the findspot is recognized as belonging to the lower members of the Hochterrasse ('Untere Hochterrasse', ibid; see below). Athanassiou (2002, 290) considers the relatively narrow occlusal surface and the increased crown height of the molar as evidence of a more advanced elephant species, while stressing the difficulties in the determination of such a partly preserved

specimen. Hans van Essen (pers. comm., 2008), after inspecting a photograph of the specimen, noted that it could be an M³ instead of an M² (hence with implications in the validity and the meaning of Schneider's measurements), and while pointing out the possible presence of a V-shaped central loop on the occlusal surface, he considers the tooth as probably belonging to *Elephas (Palaeoloxodon) antiquus*.

Mammuthus meridionalis is a late Pliocene to early Middle Pleistocene species, and its first occurrence in Europe (together with *Equus*, known as the 'elephant-*Equus* event') marks the transition from the early to middle Villafranchian (van Kolfschoten 2007). Recent studies have demonstrated that the transformations within the *Mammuthus* lineage (*M. meridionalis* – *M. trogontherii* – *M. primigenius*) were more multifaceted than a simple gradual phenomenon, simultaneous across the species' range (ibid). The interval between 1.0–0.7 Ma, during which *meridionalis* evolves into *trogontherii*, is a complex transitional period and the transitional forms "do not follow each other in an orderly chronological succession, but overlap in time" (Lister *et al.* 2005, 57). At about the beginning of the Middle Pleistocene and/or slightly earlier, a faunal change occurs, during which the straight-tusked elephant *Elephas (Palaeoloxodon) antiquus* arrives in Europe; in Italy, it is first found within the Slivia/Ponte Galeria Faunal Unit(s), bracketed between 1.1–0.6 Ma (Palombo and Ferretti 2005, 128; Sardella *et al.* 2006). *E. (P.) antiquus* is a relatively widespread species in the Middle and Late Pleistocene, with most of its occurrences associated with a regional temperate forest, although in southern Europe (Iberia, Italy and southern Balkans) it was related to Mediterranean evergreen woodland (Stuart 2005, 173). The refugial status of the latter regions have been called upon to infer a (possibly later than in the north) survival of *E. (P.) antiquus* in the south, while withdrawing from most of the rest of Europe after the end of the Eemian (Stuart 2005). The evidence from Iberia points to a presence of *E. (P.) antiquus* at ca. 40–50 ka or even later (ca. 30 ka) but is still inconclusive (ibid), whereas nothing is known of a possible late survival in the Balkans, and in Italy the species occurs at sites tentatively assigned to MIS 5a or 4, but not during MIS 3 (Palombo and Ferretti 2005). The range of *E. antiquus* in Italy overlaps that of the con-

temporaneous (Middle and Late Pleistocene) woolly mammoth (*M. primigenius*), which is a cold-adapted, open-grassland dweller, although at some sites the co-occurrence in the same stratigraphic levels is tenuous and at others it could be an artifact of time-averaging (Palombo and Ferretti 2005). In Thessaly, *E. (P.) antiquus* is well attested in the Late Pleistocene faunal list of the Niederterrasse (Milojčić *et al.* 1965; Schneider 1968; Athanassiou 2001). In 'absolute' ages, the Niederterrasse is bracketed between ca. 45 and 27 to 18 ka, on the basis of radiocarbon dates on mollusc shells (Demitrack 1986; Runnels 1988) and a lignite sample (Schneider 1968). Runnels and van Andel (1993b, 302) suggest that the earlier limit should be regarded as a minimum age and assign a tentative time-range at ca. 30 to 60 ka for the deposition of the Niederterrasse, by inferring similarities with other Greek Mousterian industries. On the basis of stratigraphic, faunal and dating evidence, the same researchers disagree with Schneider's view that the 'warm' character of the mammalian and molluscan fauna of the Niederterrasse points to a Last Interglacial age, stressing that it is in fact a "incongruous mélange of warm and cold, steppe and forest types" which may as well fit to interstadial and stadial conditions (ibid). With regard to the environmental tolerances of *E. (P.) antiquus*, Athanassiou notes (2000, 70) that the milder conditions of the glacials in south Europe would have made the area tolerable for this species even during cold stages, and hence it is not surprising to find it during MIS 6 in the Grevena basin (to the NE of and close to Thessaly).

'*Archidiskodon meridionalis archaicus*' (i.e. 'primitive *M. meridionalis*') is reported from sites in the valley of the Aliakmon river (Macedonia), where *Palaeoloxodon antiquus* is also present, whilst '*Archidiskodon meridionalis*' has been found together with '*Mammontheus trogontherii*' and '*Palaeoloxodon antiquus antiquus*' at sites in the Florina district (Doukas and Athanassiou 2003, with references therein). With respect to the elephant-representatives, such a cloudy picture is not surprising. For instance, in the early Middle Pleistocene of Italy, the possible (co-)occurrence of three taxa – *M. meridionalis*, *M. trogontherii* and *E. (P.) antiquus* (Palombo and Ferretti 2005)–, may serve as a warning. In other words, it is not impossible at all that Schneider was wrong, and the elephant molar actually belongs to *E. (P.)*

antiquus. But even if this is the case, contemplating the age of *ca.* 210 ka (provided by U/Th and discussed below) as a minimum age for the Hochterrasse is not contradicted by a possible occurrence of *E. (P.) antiquus* in its lower members. Admittedly, the problem is that such an estimate cannot be supported by the elephant molar either: the straight-tusked elephant can be found in deposits of any date between *ca.* 700 to 40 (?) ka.

In general, the mammal record of Thessaly is rather scanty and as yet poorly understood, mainly because it is for the greatest part composed of isolated finds from old collections made by amateurs or during geological fieldwork and always without a proper excavation that would provide the necessary stratigraphical data. A Late Pliocene fauna from the excavated locality of Sesklo (Athanassiou 2002) was found in deposits that are equivalent to Schneider's upper Neogene layers of the Middle Thessalian Hills, thus corroborating the chronological estimation of the latter researcher. With the exception of the aforementioned elephant molar, faunal representatives of the Early and Middle Pleistocene are missing. The Late Pleistocene fauna is better represented in a number of sites located along the banks of the Pineios to the east of Larissa, in Niederterrasse deposits, where bone material was in some instances found associated with Middle (and perhaps also Upper) Palaeolithic lithic assemblages (Milojčić *et al.* 1965; Schneider 1968; Athanassiou 2001).

In the context of a scanty faunal record, composed of isolated, unstratified finds most often collected by amateurs, and marked by significant 'gaps', (e.g. Early Pleistocene occurrences are either absent or with no value for stratigraphic correlations with the Pineios gravels, and Middle Pleistocene taxa *sensu stricto* are overall lacking), the attribution of the Hochterrasse to the Villafranchian is deemed unsatisfactory, especially since it relies on a single specimen. The age of the Hochterrasse has been refined by a U/Th disequilibrium date of ≤ 210 ka on a CaCO_3 crust from a paleosol that developed on Hochterrasse remains on the Middle Thessalian Hills (Demitrack 1986, 42). The sample was taken from a thick, truncated B horizon, of 5YR hue, with pervasive, medium-thick to thick clay films and multiple carbonate crusts (*ibid*). The soil is described as "yel-

lowish-red, clay-rich and calcic, with prominent multiple calcium carbonate crusts", the uppermost of which yielded the date (*ibid*). Another, older paleosol of "dark red, non-calcic clay with grussified clasts", is reported to be exposed against the mountain front to the north of Rodia (probably at the foothills of Mt. Lower Olympus; Demitrack 1986). In light of the soil stratigraphic approach that comprised a major part of Demitrack's work in Thessaly, her remark (*ibid*) on the poor preservation and visibility (exposure) of the Early and Middle Pleistocene soils acquires an important significance.

An U/Th date from the pedogenic calcrete coating or crust of a nodule records the time at which carbonate precipitated in this nodule; hence, the dated event postdates by at least a few thousand years the deposition of the parent material and the subsequent subaerial exposure of the deposit (and hence the onset of soil formation). To evaluate the accuracy of the U/Th method, Demitrack (1986, 22) compared U/Th dates from a paleosol, with radiocarbon dates on shells from the alluvial sediments that contain the paleosol; she considers the inferred time lag (11 to 15 ka) -between the deposition of the alluvium and the precipitation of carbonate in the soil- as correctly reflecting the necessary time for the formation of a large carbonate nodule. Although Demitrack does not specify the maturity stage of the paleosol, the Hochterrasse deposit with which it is associated would be much older, accounting for the time-span needed for the growth of the nodule and the maturation of the engulfing soil horizon. Therefore, the reported date of ≤ 210 ka furnishes a *minimum date* for the age of the Hochterrasse (*cf.* Demitrack 1986, 22); moreover, the age provided here may be substantially separated by the timing of original terrace aggradation (*cf.* Runnels and van Andel 1993b, 308; Santisteban and Schulte 2007, 2747). For the correction of the detrital Th, Demitrack adapted the method of Ku and Liang (1983) who use alpha spectrometry (AS). U-series dates obtained by AS-analyses have been recently seen as likely to represent mixed and/or low precision ages, resulting from poor sampling resolution, as AS requires large samples that may include material with complex and extended depositional histories (Sharp *et al.* 2003). Caution is drawn to such complexities that arise from the polygenetic processes of calcium carbonate mobilization and deposi-

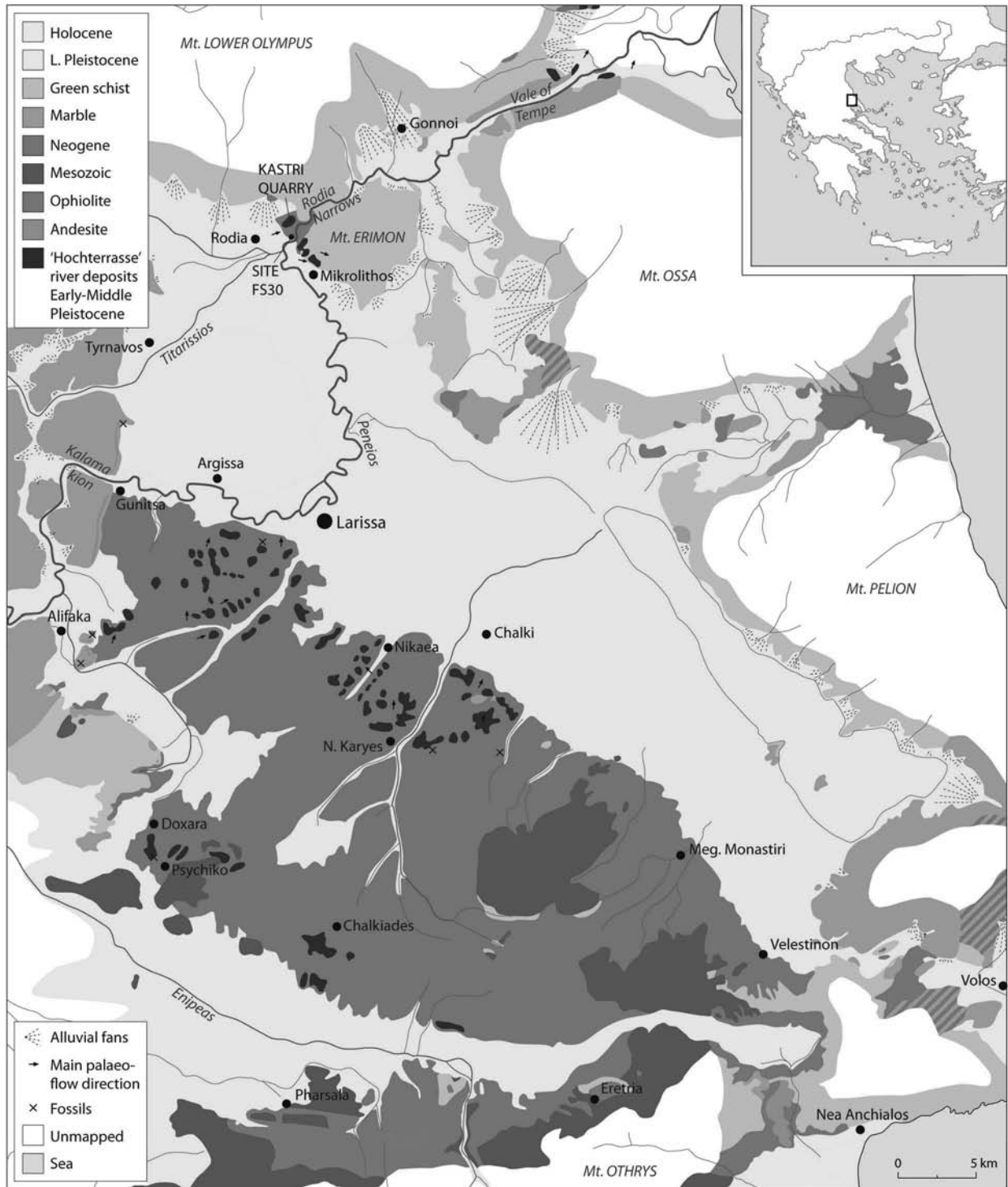


Fig. 4.21 Geological map of Thessaly, modified after Schneider 1968: Plate 66

tion, and the results can be tested against data for palaeoclimatic conditions in order to account for factors such as groundwater circulation and the overall in-

tensity of pedogenic processes (Sanisteban and Schulte 2007, 2747).

Nonetheless, the date fits well into the current chronostratigraphic framework of Thessaly, considering also that the sampled soil belongs to lower Hochterrasse deposits, for which there is another chronological indication, albeit of coarse resolution, provided by the elephant fossil (if it indeed derives from a lower unit of the Hochterrasse). It is precarious to speculate whether the dated carbonates were formed during a glacial or an interglacial climate; nonetheless, recent research on calcrete development from Spanish fluvial settings comparable to that of Thessaly showed that it is usually a phenomenon occurring during warm stages (Candy and Black 2009). As already noted though, the age of *ca.* 210 ka fits well into the general chronological framework and can be seen as an average-age constraining the upper end of Hochterrasse deposition, with a confidence level that, albeit tenuous, can be provisionally accepted.

Assessing the distribution and preservation of the Hochterrasse

Schneider's (1968) fieldwork in Thessaly included the mapping of the Early-Middle Pleistocene deposits (the Hochterrasse), as they occur on the surface, overlying the (Late Miocene-) Pliocene, predominantly lacustrine sediments. The Hochterrasse sediments are found distributed in two main areas: the first occupies part of the south-western section of the Middle Thessalian Hills, between the villages of Doxara and Chalkiades, whilst the second is on the northern border of the hills, to the west of the plain of Larissa (Fig. 4.21; App. II: 3); Schneider 1968, 22-23). The sediments of the south-west area are seen as material deposited by the Enipeas river, a tributary of the Pineios that transported gravels of chalky rocks of Mesozoic age, silicified sandstone (flysch?) and very few radiolarites from Othrys. In this area, the gravels reach altitudes up to 360 m asl and their high position can be explained by tectonic uplift (Philippon 1950), presumably related to the first tectonic phase that affected the area (*i.e.* Late Miocene/Pliocene-Early Pleistocene).

The Hochterrasse deposits of the northern distribution area belong to material accumulated by the Pineios and they are distinguished from those of the Enipeas, not only in terms of their lower elevations, but also by their greater thickness and extent of distribu-

tion, as well as by specific petrographic constituents and the degree of rolling that is evident in the gravels. Medium- to well-sorted gravels of limestone, chert, sandstone, quartzite, milky-quartz, diabase, mica schist, gneiss and granite constitute the main components, whereas thin lenses of coarse- to fine-sand and clay are found intercalated, but they usually thin out laterally.

Post-depositional, erosional surface processes have much disturbed the geometry of the original fluvial landscape, and as a consequence, it is nowadays difficult -if not impossible- to macroscopically ascertain the initial extent and thickness of morphological terraces. Schneider (1968, 23) explicitly addresses this point when he reports that a precise separation of different terrace-levels is problematic. Whereas in some places the terrace-deposits are now found as a mere thin mantle of shallow thickness (just a few meters), they are locally present in considerable thickness (*e.g.* about 25 m to the north of Neae Kariae). Owing to erosion and tectonic displacements, this discontinuity in both the horizontal and the vertical arrangement of the river gravels hampers the identification of river terraces, and, that is, also their altitudinal levels and their stratigraphic relationships (*cf.* Milojević *et al.* 1965, 9-10). This is probably why Schneider did not attempt to discriminate between 'cut-in-fill' (erosional) and 'aggradational' ('fill' or 'depositional') terrace-treads³⁴. Nonetheless, the mapping allowed him to recognize two broad subdivisions of the Hochterrasse according to the elevations of the gravel-occurrences, at 30 to 60 m (lower Hochterrasse) and at 70 to 130 m (upper Hochterrasse) above the modern Pineios floodplain, *i.e.* at 100-130 m and 140-200 m asl respectively, as the Pineios floodplain level is at *ca.* 70 m. asl at the region of Larissa. The complexity of the stratigraphic associations between the different terrace treads and their corresponding sediments -*i.e.* the questions of which treads are erosional, how many depositional fills/events are they represented, what is their chronostratigraphic ordering- is dramatically illustrated in exactly this subdivision of the Hochterrasse gravels by Jung and Schneider, after their inspection of the area in 1959: "Die

34. See section 5.2 for the nomenclature of erosional and depositional terraces.

Terrassen von 70-130 m und von 30-60 m wurden *aus Gründen einer zweckmaessigen Beschreibung, und ohne damit eine zeitliche Einordnung suggerieren zu wollen*, obere und untere Hochterrasse genannt...Alle erwähnten Terrassen sind *Akkumulationsterrassen*, (Milojčić *et al.* 1965, 8; emphasis added). The terrace-treads of both the modern, active floodplain (Late Holocene to present) and the Niederterrasse (Late Pleistocene to Middle Holocene) can be generally regarded as representing fill terraces (*i.e.* depositional or “Akkumulationsterrasse”). However, there are exceptions where the surfaces of the latter have been locally truncated by the former. In this case, the active floodplain rests discomformably on truncated Niederterrasse surfaces (*cf.* Demitrack 1986, 33); such erosional/truncated surfaces, whether refilled by modern floodplain sediments or not, represent (erosional) events that postdate the depositional fill of the underlying (Niederterrasse) sediments (App. II: 4). Therefore, even in the relatively straightforward cases of the latest two alluviation episodes of Thessaly (the Niederterrasse and the modern), terrace-levels do not necessarily represent “Akkumulationsterrassen”. This situation is even more complex with regard to the ‘upper’ and ‘lower’ Hochterrasse. For the former, whereas the base lies at *ca.* 140 m asl and its upper end rises to *ca.* 200 m asl or more, thus implying a thickness of at least 60 m, nowhere could such a thickness be securely detected. The researchers could not explain this adequately and they assumed that either the thickness is indeed 60 m (but nowhere entirely exposed), or “there are several terrace-levels inserted into each other”, or the original altitude of the terraces has been locally changed due to tectonic uplift and subsidence (Milojčić *et al.* 1965, 10). The latter two explanations imply the possible existence of erosional terrace-treads. In other words, were it not that the Hochterrasse has been poorly preserved, its reconstruction being essentially depended on isolated, discontinuous ‘gravel-pockets’, Schneider and Jung would not be so wavering in considering the *upper* Hochterrasse as *older than its lower counterpart*, as it would be the normal situation within a stepwise-terraced floodplain setting, especially when they claim that “all of the mentioned terraces are aggradation-terraces”.

Both the lower and the upper units of the Hochterrasse share practically similar lithographic compo-

nents. One significant difference in this respect is that the ‘red chert’ (radiolarite) is rare in the lower Hochterrasse. Apart from that, there is only slight divergence in terms of their general sedimentary structure and bedding, the texture, and the degree of rolling that is evident in the gravels (see and compare exposed sediments in App. II: 5, 6, 7). Most importantly, the upper Hochterrasse includes a “lime bank” and two distinct “red loam” horizons, whereas a loam-horizon “with a structure completely similar” is to be found within the lower Hochterrasse gravels as well (Milojčić *et al.* 1965, 10). I consider the lime-bank as the Bca or K horizon of a paleosol, and the red loam as corresponding to a pedogenic Bt horizon (App. II: 8). In fact, Demitrack’s (Early-) Middle Pleistocene soil “on terrace fragments upon the Pliocene hills”, from which she obtained the U/Th date, fits the descriptions of Schneider and Jung, although the latter did not recognize it as a soil (compare Demitrack 1986, 42 and Table 3 with Milojčić *et al.* 1965, 9-10).

Revisiting findspot FS 30 at Rodia: the geomorphological setting, the role of tectonism and the argumentation for an attribution to the Lower Palaeolithic

Apart from the above-described Hochterrasse deposits on the Middle Thessalian Hills, early Pleistocene fluvial sediments have been preserved on the north-eastern border of the Larissa Plain, specifically to the NE of the village of Rodia, at the point where Pineios enters the Rodia Narrows (see Fig. 4.21). The river cuts through a southern-projecting spur of the lower Olympus to the NW and the mountain ridge of Erimon to the SE, then it continues through the Vale of Tempe and finally forms its delta at the Aegean coast. According to Schneider (1968, 64), Neogene sediments up to 45-60 m-thick that are exposed at the entrance of the Rodia Narrows, testify to the existence of an older valley-remnant occupying the lowland area between lower Olympus and Erimon mountains, which was cleared-out and then partly refilled by the Pineios river in the early Pleistocene. The Neogene bedrock comprises mainly of conglomerates, with pebbles of various lithological origins intercalated with more fine-grained, medium-consolidated pebbles. The gravels of the Hochterrasse, for

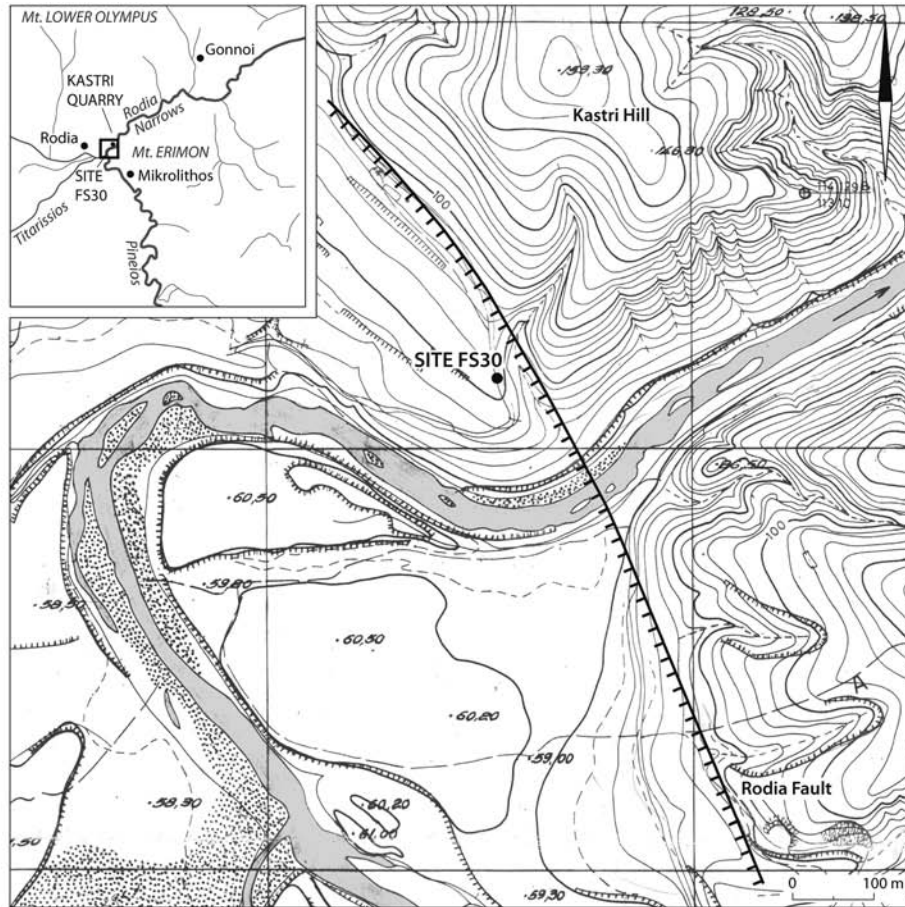


Fig. 4.22 The location of FS 30 and Kastri Hill. The main segment of the Rodia Fault System affecting the fluvial deposits at and around FS 30 is also shown

which the abbreviation HT is used hereafter, lie directly upon those sediments.

The FS 30 site is located at the west entrance of the Rodia Narrows, 20 to 40 m above the river level and around 100 m to the north of the first meander-loop of Pineios as it enters the gorge (Fig. 4.22). Runnels and van Andel (1993b, 303) report that most of the artefacts were collected from the surface of a river terrace, but some of them were found stratified in an exposed profile of that terrace. Upon discovery, more than a few of the surface finds were still embedded in outcrops of the terrace deposits, whilst some were still covered with calcium carbonate, which is the cementing material of the matrix (*ibid*). Both surface and stratified finds are in “fresh, mint condition with no signs of weathering or battering from transport downslope by erosion” (*ibid*, 304). According to the

latter researchers, all of the above observations indicate that the assemblage as a whole should be viewed as deriving from the terrace. My inspection of the assemblage (total: 65) in the storage-rooms of Larissa’s Archaeological Service corroborates the assessments of Runnels and van Andel (1993b). The material consists of large flakes with large platforms and bulbs indicative of hard percussion, bifacially flaked cores and core-choppers, but also globular or amorphous cores, and retouched pieces predominated by notched and denticulate specimens, often displaying the so-called Clactonian notches, while the Levallois technique is absent; the artefacts are overall in a fresh condition and many of them retain on their surfaces sediment-crusts from the matrix in which they were once embedded (Fig. 4.23).

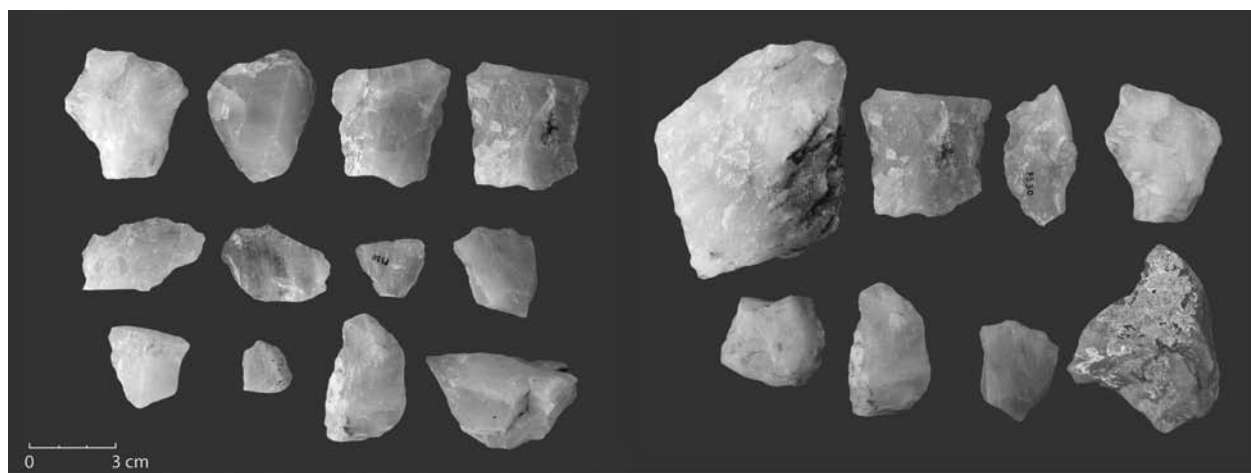


Fig. 4.23 Quartz artefacts from site FS 30

The stratigraphy of the exposed section is described as “CaCO₃-cemented, medium to well-sorted, coarse sands and sandy gravels”, with “sub-rounded to rounded pebbles of limestone and quartz, ophiolites and a distinctive reddish-brown radiolarite” (Runnels and van Andel 1993b, 305). Based on this lithological composition, the researchers correlated the artifact-yielding terrace deposits of FS 30 to Schneider’s Hochterrasse. This correlation is thought to be supported by the identification of HT gravels some hundreds of meters higher upslope from the findspot, where sands and gravels lithologically identical to those exposed at FS 30, crop out, in accordance with the position of the Hochterrasse remnants in Schneider’s map (Runnels and van Andel 1993b, 307).

Schneider observed four HT levels and the Niederterrasse in the area to the north of Mikrolithos and before the Rodia Narrows, so, most probably to the east of the river before it enters the Narrows, at the foothills of Erimon Mt (App. II: 9). In this region, the terrace-development of the Hochterrasse is, at least morphologically speaking, better preserved. Indeed, (HT?) terrace-treads can be identified already with a superficial look at the 1/5000 topographic map. Although it is impossible to conclude on the precise elevations without detailed fieldwork, the map indicates that the most prominent terrace-treads lie at elevations of *ca.* 62 m, 75 m, 88 m, 99 m and 110-113 m above the river (122 m, 135 m, 148 m, 159 m, and 170-173 m asl respectively). The four Hochterrasse levels that Schneider reports (1968, 25-26) occur at

the following elevations (all counted as above the river level, which is at *ca.* 60 m at Rodia): (1) 55 m (2) 60-62 m (3) 75 m (4) 85 m, whereas the Niederterrasse is at 15-20 m (60-80 m a.s.l.). Runnels and van Andel (1993b, 307-308) assume that the FS 30 deposits would correlate to one of these four HT-levels, “probably to one of the younger ones”, thereby implying the lowest ones; that is, either the one at 55 m or the next one, at 60-62 m. Since the FS 30 gravels are spread at 20-40 m above the river level, and the Niederterrasse is reported to occur at 15-20 m, the findspot is only a few meters above the altitude at which the Niederterrasse is deposited. To explain this, Runnels and van Andel (*ibid*) note that the findspot’s strata are tilted 12°-15° southward due to down-faulting, by faults that are visible at the gravel/Neogene contact at the entrance of the Narrows.

In search of the Hochterrasse gravels with which the FS 30 deposits have been correlated, I surveyed the ‘Kastri hill’, directly adjacent to the reported location of FS 30 (Fig. 4.22). This is a generally gently sloping hill, with three prominent peaks at 138 m, 143 m and 153 m asl. Two ravines dissect the hill in directions N-S and NW-SE, respectively. Fluvial gravels are being found at various parts of the hill’s surface and in different densities, whereas overland flow channels the gravels inside the ravines, transporting them down to the river level. At the NW side of the hill there is a large quarry (hereafter referred to as ‘Kastri Quarry’), which is the place where Runnels

and van Andel identified the Hochterrasse deposits (Runnels, personal communication 2007).

A dirt road leading inside the Rodia gorge separates the quarry into two parts, northern and southern. At both sides of the quarry there are long sections (*e.g.* up to 30 m long at the northern side) exposing fluvial deposits that cap the Neogene substratum. Because both exposures (north and south) apparently belong to a single formation, they are grouped here under the name Kastri Quarry (App. II: 10). The section of the southern side (App. II: 11) is about 10 m high, with its exposed base at 60 m above the river (120 m asl) and its top at 70 m (130 m asl). These fluvial sediments most probably represent channel- and bar-deposits of a high-energy braided river, as their bedding and structure seem to suggest. Coarse sands and gravels, well-rounded and medium- to well-sorted, are in places cross-stratified, and occasionally intercalated with lenses of clay and/or loam, as well as with layers of organic material with a characteristic dark colour (App. II: 12). The stratigraphy of the section at the northern side of the quarry is almost identical to the one described above for its southern counterpart (App. II: 13). The base of the section is at *ca.* 45 m above the river (105 m asl), whereas its top is at about 75 m (135 m asl). At least four normal faults are visible on this profile, and the cumulative fault-throw observed was estimated to be *ca.* 12 m (App. II: 14). Two (antithetic?) normal faults are exposed in the southern section as well.

The exposed gravels are small in size -the largest ones with an average diameter of less than 5 cm- and comprise basically of radiolarite, limestone, quartz, schist, serpentine, gneiss, gabbros, as well as other types of ophiolites. This lithological composition is in marked contrast to that of the Niederterrasse and leaves no doubt that the sediments exposed at Kastri Quarry belong to fluvial deposits other than that of the Niederterrasse. As they lie directly over the Neogene sediments, it is reasonable to assume that they are part of the Hochterrasse, in accordance with Schneider's cartographic indications and the assertion of Runnels and van Andel (1993b). On the other hand, it is difficult to macroscopically assess to which of the two HT units (lower and upper) they should be attributed (*if* such an attribution is deemed both realistic and necessary for Rodia in the first

place; see below). Besides the fact that the two HT units share a similar petrographic make-up, the faulting visible in the exposures has obliterated the original altitudes of the levels of the terrace-treads. In fact, at least two of the four terrace-treads designated by Schneider in his cross-section of the stratigraphy (the one exposed to the north of Mikrolithos mentioned previously, see App. II: 9), have been subjected to down-faulting, as Schneider indicates with the faults shown in his section. The profiles seen at Kastri quarry and the broader region of Findspot FS 30 reflect a similar situation, where the effects of tectonism are now masking the original stratigraphic sequence and associations. Fluvial gravels are lying even on the top of the Kastri hill (at about 150 m asl), thereby implying a thickness of more than 45 m for the deposits that crop out at the adjacent quarry. Indeed, it is very likely that the >30 m-thick deposits exposed here represent one single terrace fill (*i.e.* a 'depositional terrace'); if this is the case, then the only depositional terrace-tread belonging to this fill is the uppermost (at *ca.* 145-153 asl, *i.e.* 90-98 m above river level; App. II: 10); whilst the other observable levels are erosional, 'cut-in-fill' surfaces, *or*, alternatively, 'terrace-treads' that have been formed as a result of *faulting*, similar to that of T4 and perhaps also T2 depicted in Schneider's cross-section. Should the terrace treads visible at Kastri represent different depositional events, their associated sediments would differ in their lithological composition and/or structure, but this does not seem to be the case (hence their characterization as 'erosional terrace treads in App. II: 10); unless they are so akin that only detailed analyses could make a distinction possible, as it was mentioned before for the similarities between the lower and the upper units of the Hochterrasse. All the same, there may be considerable differences in the fluvial stratigraphy of the Rodia area compared to that of the Middle Thessalian Hills, reflecting disparities in generic/processual factors (*e.g.* local river pattern, hydrological regime, tectonic control on river's base-level) or variation in preservation conditions (tectonic displacements triggered by faults and more intense slope / erosional processes at the entrance of the Rodia Narrows). In other words, the subdivision of the 'Hochterrasse' at the area of Rodia could entail more and/or different units than the sequence seen at the Middle Thessalian Hills, and con-



Fig. 4.24 Exposed profile at FS 30. The dashed line shows the approximate position of the boundary between the two layers. 'Layer B' is overlain by recent debris from construction works

sequently it may not fit exactly into a twofold distinction between one 'upper' and one 'lower' unit.

On the other hand, should a stratigraphic partitioning of the Kastri gravels be considered possible, the Kastri terrace-fill would most likely correlate to the upper unit of the Hochterrasse, as the latter is exposed on the Middle Thessalian Hills. Notwithstanding the difficulties mentioned previously, the altitudinal occurrence of the gravels and the overall characteristics of the deposits (*e.g.* the abundance of radiolarite in the lithological composition and the exposed thickness of deposits) support an attribution to a fluvial landform equivalent to Schneider's 'upper Hochterrasse'. R. Caputo (1993; *pers. comm.* while inspecting together the stratigraphy at Rodia in 2008) considers the Kastri deposits as part of the Rodia Formation (formally defined in Caputo 1990), which represents a Pliocene palaeo-delta prograding southwards into the Pliocene-Early Pleistocene palaeo-lake. According to Caputo (2008, *pers. comm.*), the gravels at Kastri belong to the *upper Rodia Formation*, whilst their underlying red-coloured sandy sediments (mentioned above as 'Neogene') correspond to the *lower Rodia Formation*. In short, whether we consider them as the equivalent of the upper Hochterrasse, or as the upper Rodia Forma-

tion, the fluvial deposits exposed at Kastri Quarry would most probably be attributed to an Early Pleistocene depositional event (see also discussion below).

The area between the foothills of Kastri and Pineios has recently been leveled down by bulldozers for making it suitable for cultivation. As a consequence, the surfaces that once presumably belonged to a river terrace are now covered by ploughed fields. The deposits are therefore much disturbed and any attempt to macroscopically understand their original stratification or study their lithology is hampered by the fact that the sediments are highly mixed with earth-material and debris that has been transported from nearby sources. Nevertheless, radiolarite- and quartz-gravels are widely spread on those fields, but it is now impossible to unravel their provenance and association with river terraces. Although the area was carefully investigated, no artifacts were found.

The section of FS 30 is a small exposure situated at the western entrance of a ravine, at an elevation of *ca.* 20 m above river (80 m asl). Most of the section is now covered by debris, dumped here after the works for making the fields arable. Thus, only a small part of it remains exposed, with two sides at right angles, each of which is no more than 3 m long



Fig. 4.25 Closer view of the fluvial gravels of 'layer A' at the exposed section of FS 30

and 1-1,5 m high (Fig. 4.24). Notwithstanding their restricted extent, these two small profiles reveal the presence of fluvial sediments in the lowest part of the section (Fig. 4.24, 'layer A'; Fig. 4.25).

Coarse sands and gravels in various sizes are visible in what I designate here as 'Layer A'; the lithology includes all Hochterrasse-diagnostic elements, as the gravels consist mainly of radiolarite, limestone, quartz and schist (Fig. 4.25). Furthermore, the structure of the deposit is similar to that seen at Kastri Quarry, although in the latter case the gravels are generally better sorted and bedded (for a comparison see App. II: 15). Cross-stratification and clay/loam intercalations are not visible at FS 30 simply because the exposed profile is too small to include all elements seen at the >30 m-thick sections of the Kastri Quarry. Nevertheless, the general characteristics of

this layer, as well as its lithological components, provide secure evidence for a correlation with the Kastri deposits.

The two sides of the section display a dipping of the sediments towards south/southwest, in accordance with the reported "southward tilting" of the findspot strata (Runnels and van Andel 1993, 307). However, the fault that is responsible for the tilting is not exposed in those small profiles. 'Layer A' is conformably overlain by a partly brecciated layer ('B' in Fig. 4.24), the latter consisting of CaCO_3 -cemented, rounded, sub-rounded and angular stones, which include schist, quartz, limestone and ophiolites. In the photographs of the section published by Runnels and van Andel (1993b: fig. 5 and 16), it is not clear whether the artefacts were recovered from what is named here 'layer A' or 'layer B', or from both; in



Fig. 4.26 Closer view of 'Layer B'. The contact with the underlying 'layer A' is visible a little lower from the middle of the picture, immediately below the scale-bar, although it is hardly discernible because it is gradual. The scale-bar is 30 cm

fact, according to the captions of the photographs, the designated as the artefact-bearing part of the section probably *includes* what is denoted in Fig. 4.24 as 'layer B'. This layer displays essentially the same lithological composition with that of the underlying fluvialite sands and gravels of 'layer A', although it appears to contain less radiolarites. However, its semi-chaotic structure (Fig. 4.26) is contrasted to that of layer A, where the gravels are medium- to well-sorted and better bedded.

The overall appearance and structure of 'layer B' (most notably the lack of clear sorting and bedding) may be seen as indicating an episode of colluviation. If this is the case, and if the stratified artefacts found by Runnels and van Andel did belong to this layer, then the postulated provenance of the artefacts from

a Hochterrasse deposit should be deemed dubious, and (some of?) the artefacts should be considered as deriving from a more or less reworked deposit. On the other hand, my inspection of the collected artefacts at the local museum confirmed that the material lacks evidence of battering and rolling by transport (*cf.* Runnels and van Andel 1993, 305), as it would be the case with a large-scale colluvial event. Furthermore, the boundary between the two layers is gradual to diffuse, implying no substantial hiatus, whilst the tilting due to down-faulting appears to have affected both layers equally (and/or simultaneously?). Taken together, these latter observations may be considered as indicating that, if there was a colluvial episode represented by 'layer B', then it could have occurred very close either to the time of

deposition of the underlying fluvial sediments or to the time of their exposure.

Another profile, 'Section C', is exposed between the FS 30 section and the river. It has a thickness of *ca.* 7 m, its base lying at about the river level (60 m asl) and its top at *ca.* 7 m (67 m asl). Here, Neogene deposits with coarse-grained sands and gravels are overlain by 'Hochterrasse gravels' that have been much eroded, down-faulted, as well as quarried in recent times (App. II: 16, 17). The attribution of the fluvial gravels to Hochterrasse deposits is again based on their diagnostic lithology, namely the presence of the distinctive reddish radiolarite, as well as quartz, limestone and schist. The bedding and structure of the deposit are reminiscent of those described for the Kastri Quarry, and leaves no doubt that these sediments, above the Neogene strata, belong to the Hochterrasse and not to the Niederterrasse. Three fault planes (and associated slickensides) of three, almost parallel faults, are visible in this section. The fluvial sediments have been down-faulted and tilted as part of the hanging-wall of the last, southernmost fault. The presence of these faults and the occurrence of river deposits equivalent to the Hochterrasse (or, the upper Rodia Formation?) at almost the river level provide direct evidence for the effects of tectonism at the region of Rodia.

4.6.5 Conclusions and discussion

The fluvial gravels at FS 30 (*i.e.* 'layer A' in Fig. 4.24) have been correctly correlated by Runnels and van Andel (1993b) with the terrace deposits exposed at Kastri Quarry; both belong to (sediments correlative to) the Hochterrasse and most probably to a HT-fill equivalent to Schneider's upper unit, *or*, to the upper part of Caputo's (1990) Rodia Formation. In either case, their age is in all likelihood older than originally suggested (200–400 ka), probably reaching back to the Early Pleistocene, particularly if they should be regarded as part of the upper Rodia Formation. Yet, this chronological estimation still relies on a relative dating that is essentially based on the tectosedimentary history of the area and the meager indications provided by palaeontological evidence³⁵ (*cf.* Schneider 1968; Caputo 1990; 1993; Caputo *et al.* 1994). Still, if the artefacts collected by Runnels and van Andel derive from the fluvial sediments exposed

at FS 30, namely from what was called here 'layer A', they could be seen as the earliest artefacts in Greece. For the time being, however, this cannot be neither confirmed nor falsified. The artificiality of the artefacts from FS 30 is beyond doubt, the Levallois technique is indeed absent from the assemblage, the condition of the specimens precludes any large-scale reworking, and the typo-technological characteristics of the implements would support an attribution to the Lower Palaeolithic. Nevertheless, due to the recognition of what I designate here as 'layer B' and because it is possible that the artefacts may have been retrieved from that layer, the stratigraphic context of FS 30 should be deemed dubious, for it may represent a reworked deposit; in effect, the assemblage cannot be attributed to the Lower Palaeolithic *on secure chronostratigraphic grounds*. Having said that, I still consider the Thessalian basin in general and the area around Rodia and the Middle Thessalian Hills in particular as a region that needs to be further investigated for Lower Palaeolithic sites. The large lake of the Early Pleistocene would have served as a productive habitat, attracting animals and humans. Even if associated with an equivocal context, the quartz artefacts from FS 30 certainly differ from the Middle Palaeolithic specimens of the Larissa district (which are made on flint) and could be seen as at least underlying the prospects of Thessaly in contributing to the Lower Palaeolithic record of Greece.

Fault planes were identified at the Kastri Quarry at *ca.* 70 m above the river level (130 asl) and at section C at almost the river level (60 asl), whilst the presence of a fault somewhere close to the FS 30 profile at *ca.* 20 m above river (80 m asl) can be securely assumed by a number of morphotectonic indications, as well as the tilting of the gravels (R. Caputo 2008, *pers. comm.*). These faults are most probably part of the Rodia Fault System, which is a 15 km-long composite fault zone (*ibid*; App. II: 18). It includes different segments that were formed during the two major

35. Apart from the faunal remains discussed in 4.6.4, Caputo (1993, 447) cites a written communication by D. Esu for "micropaleontological dating of some samples collected in the northern Larissa plain" which confirms a "Late? Villafranchian" age for the "higher lacustrine layers", *i.e.* presumably for the upper parts of the lower Rodia Formation.

Geological Formations	Extent (km ²)	Percentage on total (%)
Quaternary ¹	1165	27. 6
Neogene ²	647	15. 3
Holocene alluvium ³	2375	56. 3
Hochterrasse outcrops ⁴	34	0. 8
Total⁵	4221	99. 0

Table 4.4 Distribution of Neogene and Quaternary formations in the lowlands of Thessaly. 1) fluvial deposits of the Larissa Plain, *i.e.* the Niederterrasse (mainly in the Tyrnavos basin) and the Holocene alluvia 2) Late Miocene to Late Pliocene (?) fluvio-lacustrine deposits outcropping on the Middle Thessalian Hills, measured on the map of Schneider (1968; scale 1: 150,000) 3) Holocene fluvial sediments of the Karditsa basin 4) Hochterrasse (*i.e.* Early and Middle Pleistocene) deposits measured on the map of Schneider (1968) 5) In total, all of the above account for the deposits covering the main lowlands of Thessaly. (1) and (3) were measured on the Geological Map of Greece (scale 1: 500,000). All measurements taken with planimeter 'HAFF no. 317'; accuracy checks by comparing readings taken on the two different maps showed insignificantly small variations in the results. Nonetheless, the values cited here are not meant to represent high-accuracy readings, but rather the general pattern of distribution.

tectonic phases: the first occurred during Pliocene to Early Pleistocene and resulted in extension with a NE-SW direction, whilst the second phase took place during Middle Pleistocene to Holocene and had a N-S direction of extension (Caputo and Helly 2005, 154). According to previous detailed morphotectonic investigations, the abovementioned faults trending NW-SE (exposed at Kasti Quarry; at section C; and indirectly at FS 30), were activated during the first tectonic phase (Caputo 1993, 453 and his fig. 5). In so far as the age of the faulting is considered well-constrained (*cf.* *ibid*; Caputo and Helly 2005), it provides a *terminus ante quem* for the age of the deposits that it affected. In fact, Caputo (1993, 453) states that “this set of faults was undoubtedly active during the Pliocene and probably later (Early Pleistocene?)”; nonetheless, there remains a possibility that some of these fault-segments were *re-activated* during the second phase (Middle Pleistocene).

Can down-faulting explain the altitudinal occurrence of ‘Hochterrasse-type’ gravels as low as 20-40 m above the river level (FS 30 section) and even at almost the river level (section C)? Caputo (1993, 455) notes that “according to the age of the involved materials, all these features quantitatively indicate some tens of meters of displacement since Late Pleistocene and some hundred since Pliocene”. Therefore, by assuming a *minimum* dislocation of about 10-20 m. we can adequately explain the occurrence of fluvial material exposed at FS 30 at *ca.* 20 m above the present river level.

The abundant evidence of faulting at the region of Rodia provides direct and indirect indications on the efficacy of tectonism in disrupting and dislocating the sediments accumulated by the ancient Pineios River. The Rodia Fault System affects the equilibrium conditions of the hydrographic system in this area, by mainly controlling the base-level of Pineios, as the activation of the fault causes a segmentation of the river’s profile upstream and downstream with respect to the fault (Caputo *et al.* 1994, 227). Subsidence caused by the Rodia Fault forces the river to aggrade in the northern part of the Tyrnavos basin, whilst subsidence related to the activity of the Omolios Fault results in regressive erosion and incision along the Rodia Narrows (*ibid*). In the former case, re-activation of the fault system from the Middle Pleistocene up to the present can be seen as responsible for the burying of the older, Early Pleistocene fluvial deposits of the Tyrnavos basin; whereas in the latter case, the movements along the Omolios fault generate erosion of the fluvial deposits in the area of Rodia. In turn, it is such erosional cycles that, on one hand obscure the geometry of the fluvial stratigraphy (*e.g.* any development of terrace-staircases), but, on the other, expose the Early Pleistocene sediments and any associated archaeological material (hence increasing their visibility).

Fluvial sedimentary sequences can be divided in two main groups according to their style of preservation (*e.g.* Bridgland and Westaway 2008a): 1) stacked deposits in superposition 2) terraced sequences. Both of these two types of alluvial preservation is found in

Thessaly: the former involves the subsiding Larissa Basin, in which the earlier phases (Early and Middle Pleistocene) are buried under the younger alluvia (Niederterrasse and modern floodplain deposits), whilst the latter entails uplifted regions and engages the Hochterrasse remains at the Middle Thessalian Hills, as well as those at the north-eastern margin of the plain, to the NE and SE of Rodia. Therefore, it is this tecto-sedimentary evolution, coupled by climatic and sea-level controls (and altogether acting upon an inherited Pliocene palaeotopography), which explains the current pattern of preservation and visibility of Early and Middle Pleistocene sediments in Thessaly. Although this is the largest lowland district, filled with fluvial deposits of the third largest river in Greece, hence a potential target for Lower Palaeolithic investigations, the available geological opportunities for the discovery of Lower Palaeolithic material are dramatically too few (Table 4.4).

Thus, the exposed Early-Middle Pleistocene sediments account for only 0.8 percent (*at most*) of the main basinal, low-gradient areas of Thessaly, whilst a more detailed mapping and/or measurement would most probably *decrease* this percentage even further. Viewed both as a net value (34 km²) and as a percentage on the total amount of lowland areas (0.8%), this figure vividly shows the restricted exposure of Early-Middle Pleistocene deposits, and hence also how exceptional the recovery of Lower Palaeolithic archaeological material is.

Key-issues for future research

Empirical evidence has led to the consensus that fluvial terrace-staircases are the result of the combined effects of surface uplift (of either tectonic or isostatic origin), which provides the impetus for incision, and the cyclic climatic triggering of fluvial activity, which largely drives the balance between depositional and erosional river behavior (*e.g.* Bridgland *et al.* 2004). On these grounds, future research on the fluvial stratigraphy of Thessaly in general and the (terrace-) development of the Hochterrasse in particular (*viz.* the pre-Niederterrasse fluvial deposits) needs to address the following central points:

1. How many glacial-interglacial cycles and/or transitions are represented by the Hochterrasse-type deposits, and to what degree was climatic

forcing coupled with tectonic controls? Terrace formation requires uplift mechanisms, related to either regional uplift or localized tectonic effects (and both can be potentially demonstrated to be affecting the course of Pineios through the Thessalian plains), but also climate-induced changes in sediment supply (*e.g.* Bridgland and Westaway 2008b). Is the formation of terraces in Thessaly a climatic or a tectonic phenomenon, or does it involve equally both factors? Schneider noted that there is no clear and conclusive evidence to answer this question, but he explicitly favored climate as the prime agent. Archives of climate change such as the pollen records of Ioannina and Kopais show that during cold spells, reduced and open vegetation cover promoted slope destabilization and enhanced erosion, resulting in relatively high levels of sediment transport and deposition (*e.g.* Tzedakis 1994; Roucoux *et al.* 2008; see also section 6.2). It is thus possible that many Hochterrasse fills may be reflecting such increased discharge regimes, prevailing either during cold periods or in cold-to-warm transitions, whilst cut-in-fill terraces could be attributed to warmer periods of reduced sediment supply and episodes of incision. Much due to their threshold-dominated nature, fluvial systems entail complex responses to climatic fluctuations and tectonic forcing, but it would not be unanticipated to find both climate and tectonic controls (periodically) acting somewhat in phase. Moreover, there is ample evidence to suggest that pre-Middle Pleistocene terraces indicate extensive alluviation and wide palaeo-floodplains, in contrast to terraces younger than *ca.* 900 ka, which designate greater vertical incision and the development of narrower valleys (Bridgland and Westaway 2008b). Future investigations can test whether such a picture is also demonstrable for the Thessalian fluvial sequence, perhaps reflected in the differences in preservation of what Schneider identified as the upper and lower units of the Hochterrasse. Within the catchment, differences in HT terrace morphology/preservation (for instance regarding their separation in vertical extent mentioned earlier) could reflect the changes in climatic periodicity/intensity introduced by the 'Mid-Pleistocene Transition', coinciding with a global increase in uplift rates

(Westaway 2002)³⁶; alternatively, this could be an artifact of preservation due to differences in channel types (*i.e.* braided versus meandering; *e.g.* Vandenberghe 2008). The study of the longitudinal profile of the Pineios, especially in places where it cuts across fault lines, could also provide further indications on the effects of tectonism in the river's history and the sedimentation/incision cycles.

2. When was the Pineios-dominated hydrological regime first established and how was the palaeotopography that it inherited? In discussing the fluvial deposits at the Rodia area, Schneider (1968, 64) notes the evidence for a (Late?) Pliocene valley remnant, through which material from lower Olympus was once transported in the Larissa basin, namely *in opposing direction to the later course of the Pineios*. Caputo and Helly (2005, 154) consider the Rodia Formation as belonging to a “palaeo-delta prograding southwards into the Pliocene-Early Quaternary Thessalian Lake”, whilst Caputo (1993, 447) asserts that “only in Middle Pleistocene the environmental conditions became typically subaerial”. Lithological analyses could aid in distinguishing different sources of the transported material (from the Pindus Mountains versus the lower Olympus) and shed light to the timing of potential drainage diversion, the emptying of the Pliocene palaeo-lake and the formation of the Middle Thessalian Hills.
3. Any resolving of the Early-Middle Pleistocene stratigraphy of Thessaly is fundamentally dependent upon the improvement of the regional chronostratigraphic framework. To this end, apart from possible applications of numerical-age dating techniques, a combination of various lines of indirect dating evidence may be applicable, albeit in varying degrees of potential success, wherever biostratigraphic, pedostratigraphic and palaeomagnetic data can be used as chronological reference-points in the ‘sequencing’ of events. For instance, Smith *et al.* (1997) have already

attempted a tentative correlation of the Olympus piedmont deposits with the soils developed on the alluvial sediments of the Larissa Basin. Palaeopedological comparisons with paleosol chronosequences from the nearby Olympus or Pindus Mountains may prove to be problematic and indeed questionable, *e.g.* by only considering the differences in geomorphological settings, but they may still yield valuable data, especially in cases where radiometric assays cannot provide conclusive results. In this respect, future attempts to better date the Thessalian fluvial sequence could take into account the relevant indications provided by the pollen records of Ioannina and Kopais (Tzedakis *et al.* 2002b; Okuda *et al.* 2001), the glacio-fluvial stratigraphy of Pindus (Woodward *et al.* 2008), and perhaps also any correlative sea-level data from the Gulfs of Pagasitikos and Thermaikos³⁷ (Lykousis 2009).

4.7 PELOPONNESUS

4.7.1 Peiros River valley

A. Darlas (1999) reports on a (unspecified) number of artefacts that he collected from the terraces of the Peiros river in western Achaia; as he notes, “most of them were discovered on the surface, a few within sections, while others were collected in the refuse left by industrial construction” (*ibid*, 307). The middle of the three fluvial terraces was the one most intensively surveyed, producing the largest number of artefacts, including those that have been attributed by the researcher to the Lower Palaeolithic period. These are “rolled and very altered artefacts”, mainly “pebble-tools and elementary cores”, thought to be derived from a “dark red clayey deposit”, although it is not specified whether the specimens were found stratified or on the surface (*ibid*). Some much rolled pebble-tools that were found elsewhere on the same terrace are considered to be also attributable to the Lower Palaeolithic (*ibid*). The middle terrace where

36. It is interesting to note here that the observed global increase in surface uplift rates around the Late Pliocene and early Middle Pleistocene largely coincides with the two major tectonic phases affecting the Thessalian landscape.

37. It would not be unreasonable to assume that sea-level oscillations might have had a direct influence on Pineios' profile downstream from the western entrance of the Rodia Narrows, perhaps indirectly affecting also its base-level upstream from the entrance of the Narrow (*cf.* Caputo *et al.* 1994, 227).

the artefacts were found is considered to date to the 'Riss' (Dufaure 1975 cited in Darlas 1999), but apart from this chronological estimation, there is essentially no other information in support of an attribution of the artefacts to the Lower Palaeolithic period. Importantly, there is also no argumentation on whether the tread of the respected terrace has been formed as a result of an erosional or a depositional event; if this is an erosional, 'cut-in-fill' terrace-level, it is of little value whether the terrace dates to somewhere between MIS 6 to 10, as implied by the ascription to the 'Riss'³⁸. All the same, it appears that the attribution of the artefacts to the Lower Palaeolithic period is in this case mostly based on typo-technological criteria, hence it remains tenuous.

4.7.2 Megalopolis Basin

Already from the beginning of the 20th century, the Megalopolis Basin (Fig. 4.27) has been repeatedly studied, first and foremost as an important palaeontological site, but also with regard to palaeoenvironmental, geophysical and magnetostratigraphic analyses, while the thick lignite seams of the basin are being exploited in opencast mines since the 1960's (e.g. Skuphos 1905; Melentis 1961; Vinken 1965; van Vugt *et al.* 2000; Okuda *et al.* 2002; Siavalas *et al.* 2009). This intramontane depression was formed during the Late Miocene-Pliocene as a result of extensional tectonic movements along a series of normal faults that define its eastern boundary (Vinken 1965). Subsistence continued in Pliocene-Pleistocene times and the basin hosted a large lake, which covered mostly the western part of the depression and was periodically turned into a shallow swamp (*ibid.*). As a result of the half-graben configuration, the lake bottom dipped gently along the western margin, where organic material accumulated, whereas detrital sediments are more abundant in the eastern part, where subsidence was more intense along the steep faults. At some point, probably in the late Pleistocene, the present drainage system was established

and the Alfeios river drained the lake, incised into the lacustrine sediments and formed river terraces.

The Pliocene-Pleistocene sedimentary sequence includes lacustrine and fluvial deposits that reach an aggregate thickness of more than 250 m. and are divided into six Formations (Vinken 1965): the Makrision and Trilofon Fm's date to the Pliocene and consist of lacustrine (lignite, marl) and fluvial (sands, gravels) sediments, respectively; the Apiditsa Fm is more than 70 m-thick and comprises fluvial sands and gravels of Early Pleistocene age; the Choremi Fm dates to the early and middle Pleistocene and is subdivided into the Marathousa and Megalopolis Members, which include lacustrine and fluvial sediments, respectively; the Potamia and Thoknia Fm's date to the Middle-Late Pleistocene and essentially mark the end of the limnic conditions and the development of a fluvio-terrestrial depositional regime; finally, the latter Fm's are overlain by Holocene coarse clastic sediments deposited by Alfeios and its tributaries. Of particular interest to this study and to future archaeological investigations is the middle Pleistocene Marathousa Member, which contains lacustrine clay, silt and sand beds with freshwater bivalves and ostracods, intercalated with thick lignite seams (Vinken 1965). The rhythmic alteration of lignite seams with detrital layers reveals a pattern of large- and small-scale lithological cycles. Cyclostratigraphic and palynological studies (van Vugt *et al.* 2000; Okuda *et al.* 2002) indicate that the large-scale cycles represent glacial-interglacial alternations related to the eccentricity-forced periodization (*ca.* 100 kyr), while the small-scale cycles relate to precessional forcing (*ca.* 20 kyr). Most likely, the detrital beds were formed during cold and dry periods when reduced vegetation promoted erosion, whilst lignite and organic layers accumulated during periods of warmer and more humid conditions (van Vugt *et al.* 2000).

Sickenberg (1975) identified eleven species of large mammals from the Marathousa Member, including *Mammuthus (Archidiscodon) meridionalis*, *Hippopotamus antiquus*, *Praemegaceros verticornis* and *Stephanorhinus etruscus*; based on correlations with other European faunal assemblages (e.g. Ponte Galeria, Voigtstedt, Petralona) he dated the fauna to the Early Biharian (Early and Middle Pleistocene). A more recent study of the Marathousa fauna identified

38. For artefacts found on the surface of fluvial terraces, it is important to distinguish between fill (depositional) terraces from 'cut-in-fill' (erosional) terrace-treads. This is discussed further in section 5.3.

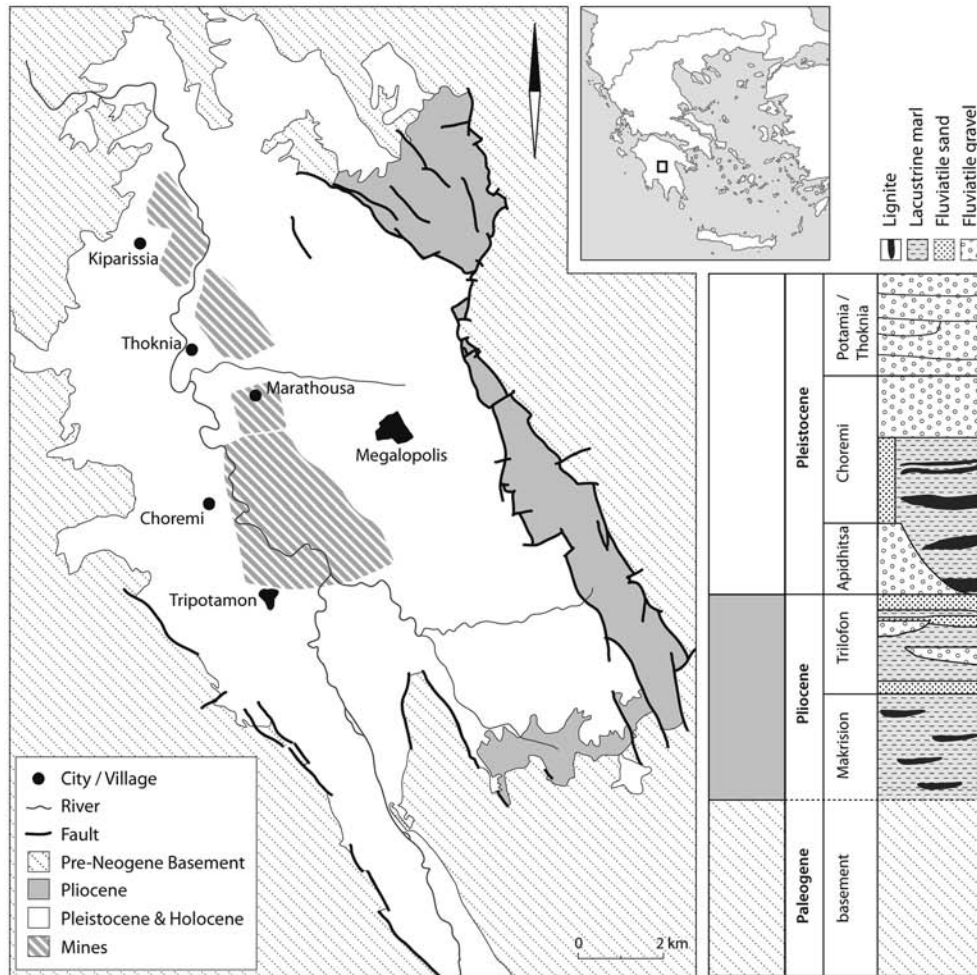


Fig. 4.27 Geological map and stratigraphic column of the Megalopolis basin. Modified after van Vugt *et al.* 2000: fig. 1

the voles *Pliomys* aff. *episcopalis*, *Mimomys* aff. *savini*, *Mus* cf. *spretus*; on the basis of the faunal composition (particularly the representatives of the genus *Mus*) and an assumed continuity in the studied section, it was concluded that either the entire Marathousa Member dates to the Late Biharian, or the lower part is of late Early Biharian and the upper part of Late Biharian age (van Vugt *et al.* 2000). Although the correlation of a small-mammal biozonation (Biharian) to a large-mammal biozonation can be problematic, the chronological estimations of the two studies are not contradictory (*ibid.*). Moreover, a magnetostratigraphic analysis identified the Matuyama-Brunhes polarity reversal near the base of the section (*ibid.*). Thus, on the basis of the palaeomagnetic and palaeontological data, as well as an ESR date (of ca. 370 ka) from the upper part of the se-

quence (Okuda *et al.* 2002), the Marathousa Member is considered to date to the middle Pleistocene (ca. 950-300 ka; van Vugt *et al.* 2000).

The faunal material that Sickenberg (1975) studied is considered to have been retrieved from the Marathousa layers. Most of the fossils from this collection were not found *in situ* in the exposed sections, but were collected from secondary deposits “*within colluvium which has accumulated at the slope of a ridge formed of the silt, clay and marl in the Marathousa beds*” (Sickenberg 1975, 62); therefore, the fauna is considered to “*originate from the Marathousa layers*” (*ibid.*, 26, translated from German). The researcher notes that it is not the aim of his study to investigate the primary locations of the material, but he remarks that the fossils’ state of preservation indi-

cates short-distance transport from the immediate surroundings (ibid). If I read Sickenberg correctly, he considers that the faunal assemblage certainly derives from the Marathousa Member, but it is not possible to pinpoint the exact primary location of each fossil in the individual layers of the Member. In support to this conclusion, he notes the ‘unity’ (“Einheitlichkeit”) of the fauna, the lack of evidence for contamination by more recent deposits and the absence of any subfossils. That said, two more of Sickenberg’s remarks need to be noted here (ibid, 26): (1) “*Blossgelegt und verschwemmt konnten auch einzelne Knochen und Zähne in einigen der zahlreichen kleinen Wasserrisse aufgefunden werden*”, and (2) “*Es [i.e. das Fundgut] kann vielmehr als synchron – (z. T. allochthon, da teilweise etwas umgelagert) – bezeichnet werden*”. The aforementioned remarks are important because Sickenberg also identified a human upper third molar among the faunal material; as with the rest of the assemblage, he considered that the tooth derives from the Marathousa Member (excerpt of Sickenberg’s letter to G. Marinis in 1973, cited in Sickenberg 1975). Sickenberg (ibid) wrote that this could represent the oldest evidence for the presence of hominins in Europe and that an assessment of the tooth would be presented in a separate study. Sickenberg’s study never came out due to his sudden death in 1974 and it was only in 1979 that Xirontiris and colleagues published the first study of the human molar. Xirontiris *et al.* (1979) carried out a microscopic and comparative odontometric analysis, and they were able to confirm the hominin status of the tooth, but could not assess its phylogenetic classification. After about thirty years since that first and only study, the tooth is currently being re-examined (Harvati *et al.* in prep.).

Despite this uncontested type of evidence for the presence of hominins in Megalopolis, systematic archaeological investigations have not been carried out in the basin yet. However, Darlas published in 2003 a report on Palaeolithic finds from Megalopolis. Darlas (2003) investigated the fluvio-lacustrine deposits near the village of Isoma Karyon (nearby and to the west of Thoknia village; Fig. 4.27) at a locality where in the early 1900’s Skuphos unearthed abundant faunal remains, including fossils of *Archidiscodon meridionalis cromerensis*, *Paleoloxodon antiquus antiquus* and *Mammuthus primigenius*. From a total of

thirty-seven lithic implements, twelve were found by Darlas stratified, half of them in an exposed profile that yielded also a fossil of a large mammal; the condition of those implements indicates that they have not been transported (ibid, 30). The rest twenty-five lithics were collected from the surface, some of them close to the aforementioned section and others from the top of the fossiliferous deposits, as well as from other nearby locations (ibid). Darlas discusses several problems pertaining to the provenance and the relative dating of the lithics (ibid, 30, 34-35): firstly, the place that Skuphos excavated has been destroyed by erosion and road constructions, and it is impossible to correlate the artefact-bearing stratigraphy with the one that yielded the fossils found by Skuphos; secondly, it is not clear whether the sediments that Darlas observed are in a primary or secondary position; and thirdly, the lithic artefacts are too few and non-diagnostic in terms of their typo-technological characteristics, although the researcher notes that the overall picture would suggest an attribution close to the Middle-Late Pleistocene boundary. Darlas also remarks (2003, 35) that all geological studies correlate the so-called ‘Isoma layers’ (namely the layers at the locality where Skuphos unearthed the fossils) with layers of the Marathousa Member, but Dufaure (cited by Darlas) correlates them with layers of the Megalopolis Member. Finally, it has to be underlined here that, according to Darlas (ibid), lithic artefacts have been found also in other locations of the basin; importantly, a flake made on flint and three mammalian bone shafts, which bear traces of anthropogenic fracturing, were found within lignite layers of the Thoknia mine.

Clearly, further work needs to be done in order to test the possibility that the artefacts found by Darlas date to the Middle or even to the Early Pleistocene, which would be the case if the associated sediments could be securely shown to be in primary positions and correlative to the stratigraphy revealed by the excavations of Skuphos (Darlas 2003, 35)³⁹. Evidently, the basin of Megalopolis is one of the most promising (if

39. Darlas notes that according to Melentis, who later studied the fauna from the investigations of Skuphos, the condition of the fossils indicates that they were collected from undisturbed deposits (see references in Darlas 2003).

not *the* most promising) place for future archaeological research in mainland Greece. It is one of the few basins of Greece where thick lacustrine deposits have been preserved, potentially burying archaeological material in primary contexts of fine-grained sediments, accumulated in a low-energy environment with a rather continuous sedimentation; this is important not only for the degree of preservation of anthropogenic material, but also with regard to plant and faunal remains that are valuable for palaeoclimatic and palaeoenvironmental reconstructions. This is also the only lacustrine basin in Greece which has yielded both human remains and lithic artefacts. Although the faunal assemblage that Sickenberg (1975) studied was not retrieved from primary locations, there are credible arguments to consider it as

deriving from the Marathousa Member and, in this case, the hominin molar should date somewhere between *ca.* 350-900 ka, according to the latest chronological constraints on the Marathousa Member by van Vugt *et al.* 2000. Hence, on the current evidence, and considering the date of 350 ka as a *terminus ante quem*, the tooth from Megalopolis is in all likelihood the oldest hominin fossil in Greece. In sum, the evidence for an early-middle Pleistocene human presence in a palaeo-lake setting, for which a relatively well-established chronostratigraphic framework is already in place, exemplifies the potential of Megalopolis for yielding Lower Palaeolithic sites as old and as important as the famous sites of Isernia in Italy or Gesher Benot Ya'aqov and even 'Ubeidiya in the Levant.

5 – Pleistocene deposits and the absence of stratified Lower Palaeolithic evidence: two case-studies

5.1 INTRODUCTION

Excluding the investigations at Petralona and Apidima caves, all of the material that has thus far been reported as of (possibly) Middle Pleistocene age has been collected during survey projects (*e.g.* Cherry and Parkinson 2003). The preceding examination showed that many of the finds reported as probably belonging to the Lower Palaeolithic, were either not associated with any stratigraphic context at all, or their inferential attribution to a geological context is more or less problematic. Should this overall lack of stratigraphic control be attributed to the inability of researchers to assess provenance data? Does it stem from insufficient apprehension of the importance of this contextual control for collection strategies? Or is it that, even if every survey project accounts for this need, not every project is able to fulfill it, due to project-inherent reasons? Although positive answers to one or all of the above questions may be given with regard to specific examples, in most of the cases none of the above seem to be primary reasons: more often than not, researchers reporting Palaeolithic finds are fully aware of the significance of provenience investigations, they do engage serious efforts in that direction, and they are almost always assisted by at least a few specialists in geological disciplines.

The shortage and/or total lack of stratigraphic control appears to be first and foremost a result of geomorphic processes and not research-specific biases. To support this argument, I will briefly discuss in this chapter preliminary results from two survey projects in which I participated. Considering them in a historical context, both can be regarded as relatively representative of two main types of survey investigations, which have so far provided the frameworks for the collection of data on the Palaeolithic of Greece (*cf.* Cherry and Parkinson 2003). Although

even more target-specific than its predecessors, the Aliakmon Project followed the lines of the pioneering works of Higgs and Vita-Finzi (and, later, G. Bailey) in having an explicit focus on the Palaeolithic period. In contrast, the still-ongoing Zakynthos Archaeology Project (ZAP) aims to relate the diachronic and spatial distribution of finds to landscape dynamics, and in that respect, it is in line with other previous research with a diachronic dimension (*e.g.* the Nikopolis Project in Epirus). The survey of the deposits of the Aliakmon river did yield artefacts that would fit perfectly in any known Lower Palaeolithic context, but it failed to tie the finds to the local stratigraphy. The ZAP is still in progress, but, likewise, it has so far been unable to relate the Palaeolithic implements (which in this case come in thousands) to a geological setting; one notable exception (see below) is regarded as only confirming the rule. The case of the ZAP is important in one more respect: here, the bulk of the material is of Middle and -to a lesser degree- Upper Palaeolithic morphology, a picture emphasizing the fact that, wherever landscapes are much disturbed, the lack of stratigraphic control is a problem for almost any kind of finds from the Quaternary. If goals are not at issue and technical constraints not always a good excuse, it is most likely the available geological opportunities that prevent us from realizing what the Latin verb *contexere* originally means, namely ‘to weave together’ artefacts with a four-dimensional spatio-temporal matrix.

5.2 ALIAKMON SURVEY PROJECT

The Aliakmon survey project was a three-year project (2004-2006) of investigations in the basin of the Aliakmon river, Western Macedonia, North Greece (Fig. 5.1). The results from the first two years of the project have been published elsewhere (Panagopou-

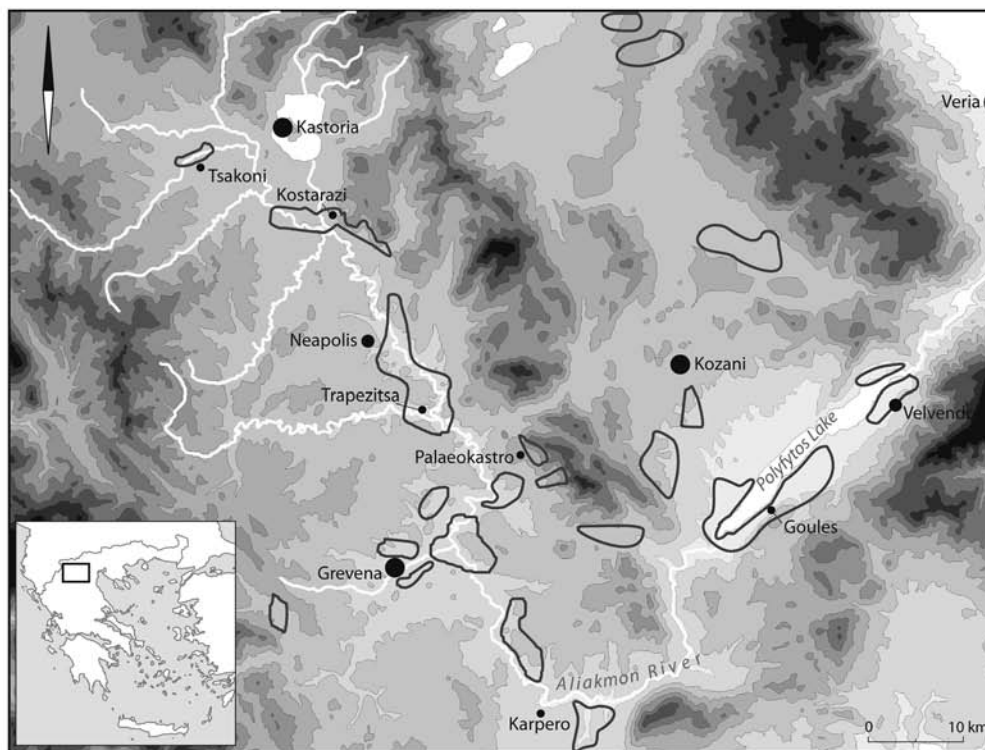


Fig. 5.1 Aliakmon Project: map of the survey area. Modified after Harvati *et al.* 2008: fig. 2.1

lou *et al.* 2006; Harvati *et al.* 2008) and the following review and discussion is based mainly on those publications as well as on my own observations as a member of the survey team during the last two field-seasons. It should be noted here that results from a pilot dating-study (palaeomagnetism, ESR) of the Aliakmon river terraces are pending.

In view of the overall lack of Lower Palaeolithic sites in South-Eastern Europe in general and in Greece in particular, the aim of the project was to locate early Palaeolithic, palaeoanthropological and palaeontological sites, which could potentially add valuable information to the debate about the earliest peopling of Europe. With its explicit focus on Early and Middle Pleistocene landforms, this research can be regarded as the first systematic survey of Lower Palaeolithic sites in Greece. The targeting of fluvial and fluvio-lacustrine deposits in Western Macedonia was justified on the basis of three main premises: (1) Lower Palaeolithic evidence in European/Mediterranean landscapes is most commonly associated with this kind of sedimentary contexts; (2) the Aliakmon, the longest river in Greece, offers the most extensively

out-cropping fluvial deposits of this period (Late Pliocene to Late Pleistocene) in northern Greece: Epirus contains very restricted drainage basins, whilst Early and Middle Pleistocene river sediments in Thrace are deeply buried under younger alluvia; (3) Macedonia had previously yielded not only (presumably Lower) Palaeolithic artefacts (see 4.3.2)⁴⁰, but also significant Pliocene and Pleistocene faunal material; considering these indications, as well as the physiographic course of the river, it is likely that the Aliakmon fluvial system could have dictated dispersal routes connecting the northern Balkans with the Greek Peninsula and -in extent- Asia Minor and the Near East, as the region of western Macedonia is the

40. That is, the handaxe found by E. Higgs in Palaeokastro (Kozani prefecture), but also another (unpublished) biface made on a green volcanic material, which was found during works of the local archaeological service on the shores of the Polyphytos artificial lake, close to the locality from which we, too, collected artefacts later. Note that another survey project in the area of Grevena has documented the presence of Middle Palaeolithic artefacts on highland plateaus (above 1000 m; Efstratiou *et al.* 2006).

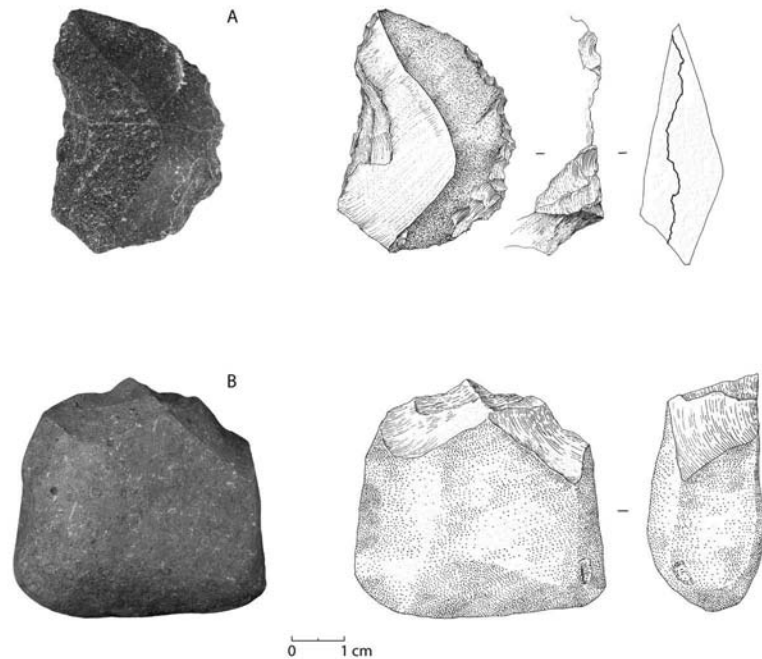


Fig. 5.2 Aliakmon survey project: lithic artefacts from the localities of Polemistra (A) and Karpero (B). Reproduced after Harvati *et al.* 2008: fig. 2.3 and fig. 2.4

main natural passage between north-western and north-eastern Greece.

The methodology of the research was based on selecting specific areas for surveying, according to a set of geological and geomorphological indicators, which were assessed by cartographic means and geological reconnaissance. After selecting the areas, the survey teams concentrated on the systematic investigation of the longitudinal profiles of the river terraces, as well as on examining alluvial fans and fluvial deposits of tributary streams that are often exposed in ravines. Despite serious efforts, we did not find any artefacts *in situ* in the exposed profiles. In total, seventy-four specimens were collected from the surface. In lack of stratigraphic context, it is not possible to firmly ascribe any of the artefacts to a specific period of the Palaeolithic. Nonetheless, two assemblages have been reported as of probable Lower Palaeolithic age, but only on the basis of the morphological characteristics and technological features of the artefacts (Harvati *et al.* 2008, 18). At the locality of Polemistra, nineteen artefacts, made on a coarse-grained volcanic rock, were collected from the lakeshore of the Polyphytos artificial lake. Nine

artefacts made on the same raw material (probably andesite or basalt) were recovered from the surface of a river terrace at the locality of Karpero. Both assemblages consist of cores, choppers, chopping-tools, large primary flakes and a few bifacially-worked tools (but no typical bifaces, such as handaxes; Fig. 5.2). A somewhat similar picture is drawn with regard to the palaeontological findings, although -in contrast to the lithics- some of them were found in stratigraphic context. Relatively dense accumulations were observed at a number of places along the Livakos stream, a tributary of the Aliakmon, which yielded a fauna dominated by *Equus* and probably dating to the Late Pliocene-Early Pleistocene. At the findspot of Kostarazi, several fossils were collected from within a quarried part of a river terrace, including skeletal parts of a proboscidean, remains of a large ruminant (possibly *Megaloceros*) and equids.

Considering the fact that this project had very focused research objectives and targeted very specific areas for investigations, the archaeological and palaeontological findings were arguably meager in numbers and of rather low informational value. Most

importantly, the question to be addressed is how to explain the conspicuous absence of stratified lithic artefacts and the overall scarcity of *in situ* animal fossils. In all likelihood, the most plausible answer to this question lies in what I consider as one of the major conclusions deduced by the geological work of the project: the fact that the Pleistocene fluvial system of the Aliakmon appears to have been principally erosional, rather than depositional (Panagopoulou *et al.* 2006).

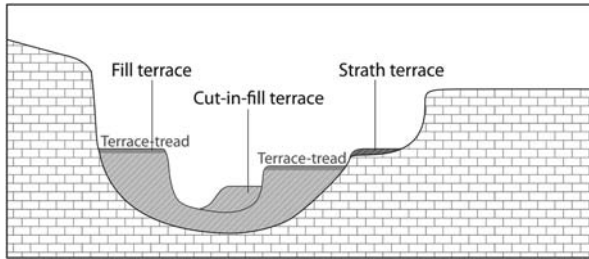


Fig. 5.3 Schematic cross-section of a river valley showing depositional ('fill') and erosional ('cut-in-fill'; strath) river terraces

River terraces are abandoned river channels and floodplains, and are formed when changes in equilibrium conditions force rivers to incise their former valley floors (Fig. 5.3). In the case of *depositional* terraces, sediments were accumulated by either vertical or lateral alluvial accretion, and the surface of the terrace, called tread, represents the uneroded surface of the former level of valley fill; depositional terraces are sometimes called 'fill' or 'aggradational' terraces. *Erosional* terraces are formed when a valley floor becomes truncated by lateral fluvial erosion and subsequently stranded by down-cutting (incision). There are two types of erosional terraces: (1) those that are created when the river cuts down its own, previously deposited alluvium; these are sometimes called 'fill-cut' or 'fill-strath' terraces, but I prefer the use of the term 'cut-in-fill', which is more accurately descriptive; (2) those that are formed when the river erodes the bedrock of the valley; these are called strath terraces. Most of the Aliakmon fluvial terraces are erosional (either of strath or cut-in-fill type), and this reality has important implications not only for the preservation of archaeological material but also its potential emplacement within a regional chronostratigraphic framework.

In most cases, the treads of both erosional and depositional terraces represent palaeo-surfaces that have been in existence since the time of their formation. What does this mean in archaeological terms? Consider that such a tread (palaeo-surface) was formed at, say, 500 ka; artefacts resting today on that surface could have been discarded by hominins at any time between 500 ka and the present. This is the reason why the project focused on the examination of longitudinal profiles, instead of the surfaces of terraces. There is, though, one important point to take into account. In the case of an erosional tread, any artefact scatter lying on the surface will represent an episode of discard much younger than the time-span represented by the underlying deposits (and this is most dramatically exemplified in the case of strath terraces). In contrast, artefacts resting on a depositionally-formed tread *may be* chronologically close to the time-span during which the terrace (and its tread) was formed. For example, if an assemblage that is discovered on the surface of a depositional terrace comprises artefacts of the same raw material and typo-technological characteristics, it can possibly be assumed that the assemblage has been eroded out of the terrace deposits (*e.g.* by deflation) or it has been lying there (undisturbed) since the formation of the terrace. Of course, both of these assumptions need to be cross-checked by various taphonomic and geomorphological indications, and are most convincingly confirmed when similar artefacts are found also stratified in an exposed section of the same terrace; if confirmed, any possible dating of the sediments of the terrace can furnish a chronological estimate for the artefacts lying on it. The point is that no such assumption can be made when artefacts are found on the surface of an erosional terrace: in this case, the artefacts are *de facto* out of context and their provenance can hardly be inferred, let alone demonstrated; needless to stress, the age of the underlying sediments is of no value with respect to the artefacts. This distinction, only sketchily described here, is very important also when assessing the possibility that an artefact-concentration found on the surface may be indicative of more artefacts being buried in the subsurface. In other words, subsurface investigations (*e.g.* with test-trenches) guided by surface artefact clusters are meaningful only in the case of depositional terraces. In the same vein, fossils found on the surfaces of an erosional terrace cannot be corre-



Fig. 5.4 Palaeontological locality of Kostarazi: one of the few instances where a depositional terrace is extensively preserved. For scale, note the cars in the centre-left of the picture. As evident in the photograph, only a small part of the longitudinal profile is exposed, at a locality that is being quarried for commercial purposes; this outcrop yielded a number of large-mammal fossils, but no artefacts

lated to the time of the formation of this particular terrace, as they may belong to a depositional event that is represented by an older (and higher) terrace, which was subsequently eroded down to a lower level.

The geomorphological examination of the study area showed that the depositional or erosional character of the terraces varies from place to place as a result of the complex history of the fluvial system (Harvati *et al.* 2008, 16). Coupled with an overall lack of dates (ibid), it was hardly possible to make secure correlations between terraces found on different elevations—a task that, especially in tectonically active regions, is bound to be problematic, because relative heights of terraces may vary along different reaches of a river due to, for instance, varying uplift histories. Naturally-exposed profiles in the area are overall scarce and quite often the team's efforts were restricted in examining the few quarries that exist in the area (Fig. 5.4). Depositional terraces are preserved only in the form of spatially-confined patches, a fact that further minimized the chance of them having exposed sections. Thus, in identifying the predominance of erosional terraces and realizing the archaeological consequences of this picture, the methodological strategy of the project had to be adjusted accordingly. At a certain point, it was evident that devoting most efforts to the investigation of the

few available outcrops of depositional terraces was not returning any results in terms of find numbers; on the other hand, the intensive scouting of terrace-treads would most probably increase the collection of archaeological material, but this material would have been mostly of secondary context and hence of a restricted value. In retrospective, I believe that concentrating on the search for stratified occurrences was the correct strategy, notwithstanding the fact that our efforts were unsuccessful in that respect. The project may have failed to provide stratigraphically-supported evidence for a Lower Palaeolithic human presence in Western Macedonia, but it did provide indications for another significant issue: that the absence of evidence should not be uncritically interpreted as evidence of absence, for reasons that are briefly explained below.

On the published accounts, a total of 169 fossils were collected. The faunal material includes proboscideans (*Mammuthus* cf. *meridionalis*, *Elephas antiquus*), equids, bovids, canids, cervids, rhinocerotids, suids and possibly hippopotamids (Harvati *et al.* 2008). Considering that almost the entire faunal collection consists of large-sized mammals (the few specimens from a rodent are also from a large taxon), and particularly species with skeletal parts much larger than that of hominins, it can be argued that the prevailing taphonomic circumstances (during and

after terrace formation) would not have overall favored the preservation of the smaller-sized and more fragile hominin remains.

The absence of stratified lithic artefacts or human remains is largely explained by the fact that depositional events are very fragmentarily preserved in the stratigraphic record of the Early and Middle Pleistocene Aliakmon fluvial system: depositional occurrences are restricted to only a few isolated and spatially confined patches of terraces, thereby minimizing the chances of discovering *in situ* finds. Palaeontological finds were scarce, not only inside the exposed profiles, but also on the surfaces of both depositional and erosional terraces. If we take the total number of fossils and of lithics at face value, considering them as the only ‘signal-at-hand’ for the presence of non-human and human species respectively, the non-human signal is not stronger enough to suggest a real absence of humans as opposed to the presence of other species. Instead, both signals seem to be relatively equally biased by taphonomic factors. On the current evidence, humans were certainly present in Macedonia and all of its surrounding regions during the Late Pleistocene, and were definitely present in the nearby Chalkidiki peninsula even earlier, during the Middle Pleistocene (Petalona Cave). As mentioned earlier, the Aliakmon drainage system connects north-eastern with north-western Greece and the northern Balkans with the southern parts of the Greek Peninsula⁴¹, so that it is difficult to envisage Western Macedonia as a blank area in-between populated regions, *e.g.* during the Middle Palaeolithic. The low and not yet stratigraphically attested Early and Middle Pleistocene human signal in Western Macedonia is essentially an artifact of geological biases; this assessment is supported by the fact that it largely involves also the Late Pleistocene human signal, as far as the results from the Aliakmon project are concerned: none of the possible Middle and Upper Palaeolithic finds that we collected was discovered *in situ* in the terraces.

Hence, the available geological opportunities for the preservation of stratified archaeological material within fluvial landforms are extremely small in Western Macedonia. The parameters that biased preservation are to be found in the incision history of the Pleistocene Aliakmon. This history is expected to have been influenced mainly by climatic factors and especially the conditions characterizing glacial stages (*cf.* Gibbard and Lewin 2009) and the transitional periods during climatic switches (*cf.* Vandenberghe 2008). The erosional terraces of the Aliakmon could have formed due to and during the fluctuating cold-climate conditions within glacial stages; the few aggradational episodes surviving in the record could relate to the peaks of the glacial spells, whilst the paleosols that we observed intercalated within terrace deposits would correspond to interglacial periods of overall fluvial quiescence and landscape stability (*cf.* Gibbard and Lewin 2009). Uplift was certainly an important agent at work, but the driving forces behind it are most likely of regional character and tectonic origin (*cf.* Goldsworthy and Jackson 2000). For example, probably resulting from the Pleistocene activity of the Rimmio-Servia normal fault system, the Neogene sediments in the hanging-wall of this system have been tilted to the south-east, with several streams flowing down-dip into what is now the man-made Polyfyto Lake. The artefacts of Lower Palaeolithic morphology that we collected from the shores of the lake (‘Polemistra’ locality) probably derive from Early/Middle Pleistocene terrace deposits to the north-west of the lake. It is very likely that these deposits were first eroded by the streams when the tilting occurred as a result of fault activation. At present, what we see is small and thin remains of those depositional terraces that patchily cap the Neogene substratum, close to the findspot of Polemistra. And what we find is Lower-Palaeolithic-looking artefacts for which we can only hypothesize -rather than demonstrate- that they derive from those now-eroded terraces.

5.3 ZAKYNTHOS ARCHAEOLOGY PROJECT

As part of the Ionian Islands, Zakynthos is situated between the Hellenic subduction zone and the zone of continental collision between the Apulian and Greek platforms (Le Pichon and Angelier 1979). Be-

41. The Aliakmon drains the northern part of the Mesohellenic Trough, a molassic basin that would have served as a natural route between mountain ranges since the early Tertiary.

cause of its position, the island has been subjected to a highly active tectonic regime that includes both extensional and compressional movements, manifested by frequent and intense seismic events (e.g. Lagios *et al.* 2007). Nonetheless, Zakynthos preserves the most complete sedimentary archive of the Ionian Islands, with rocks ranging in age from Cretaceous to Holocene (Duermeijer *et al.* 1999). In contrast, its archaeological record is extremely poor, compared to the evidence from the other islands and the adjacent mainland (Van Wijngaarden *et al.* 2006). Historical sources testify to the importance of Zakynthos in Mycenaean, Classical and Roman times, but standing architectural remains from these periods are overall lacking (*ibid.*).

The Zakynthos Archaeology Project (ZAP) aims to relate the spatio-temporal distribution of archaeological remains to the landscape dynamics, hence geoarchaeological and geomorphological investigations are central in the project's program (Van Wijngaarden *et al.* 2006; 2007; 2009). Three study areas were selected to be surveyed, because they include all of the main geological formations and represent different landscape categories. Methodologically, the basic survey unit is the 'tract', which is defined by topographic and geomorphologic features; within tracts, field-walkers survey at 5 m intervals and collect all archaeological finds they encounter (Van Wijngaarden *et al.* 2007). Previously, lithic implements that have been collected as surface finds were attributed to the Middle Palaeolithic (Kourtessi-Philippakis 1999) or to the Mesolithic and later periods (notably Bronze Age; Sordinas 1970) practically on the basis of their techno-morphological traits. Thousands of lithic artefacts have been so far collected during the ZAP 2005-2009 field seasons, but with very few exceptions (see below) all of them are surface finds; moreover, most of the material is typologically non-diagnostic, whilst much of it is significantly weathered and/or patinated. In most cases, artefacts of -mostly Middle- Palaeolithic morphology (and usually patinated) are found mixed with typologically Neolithic or Bronze Age (unpatinated) lithics and/or pottery sherds from late prehistoric and historic periods. This 'background noise' associated with the *mélange* character of the collections appears to be a wider phenomenon, as it equally affects lithic and pottery finds. As a general pattern, the majority

of the material from all find classes occurs in a much fragmented and worn condition, it is usually typologically non-diagnostic and is found in rather low densities. Below, I will discuss why Lower Palaeolithic finds seem to be missing from Zakynthos and why Palaeolithic material -in general- is hardly to be found in stratified positions. Note, however, that the discussion here is based only on macroscopic observations assessed during limited geological reconnaissance.

During the Pliocene, a westward propagating fold and thrust system resulted in the uplift of the Vrachionas anticline in western Zakynthos, whereas activity of the Ionian Thrust segmented a pre-existing Miocene basin into the sub-basins of Alikanas in the centre of the island and Geraki in the southeast (Fig. 5.5; Zelilidis *et al.* 1998). Thrusting continued throughout the Quaternary, causing the progressive uplift of Pliocene and Early Pleistocene sediments, while from the early Pleistocene onwards rapid basin subsidence affects the landscape (*ibid.*). Thus, an important palaeogeographic change of the (late Miocene) basin slope setting occurs already during the Pliocene, culminating in the continued uplift of western Zakynthos and subsidence of the Zakynthos Channel basin from the early Pleistocene onwards. Sedimentological evidence from south-east Zakynthos points to a tectonic influence (faulting) in the accumulation of sediments already from Late Pliocene and throughout the Quaternary (Zelilidis *et al.* 1998), and palaeomagnetic data record a rapid tectonic event occurring after 0.77 Ma and associated with late Pleistocene uplift in (mainland) Greece (Duermeijer *et al.* 1999). This tecto-sedimentary evolution explains why Pleistocene deposits are today limited to the Geraki basin (Vassilikos Peninsula) in the south-east and to a small area in the east, around Zakynthos town: by the Middle Pleistocene, the loci of sedimentation were largely restricted to the Zakynthos Channel basin and its margins, *i.e.* the Geraki basin. In the western part of the island, the Vrachionas Mountain constituted the major source area for sedimentation; on this mountainous setting, Pleistocene sediments occur only as isolated patches that have been preserved in depressions formed in the karst terrain (e.g. *terra rossa* deposits, most probably of late Pleistocene age, in dry, karst valleys). Pleistocene sediments on the centre of the island (*i.e.* the

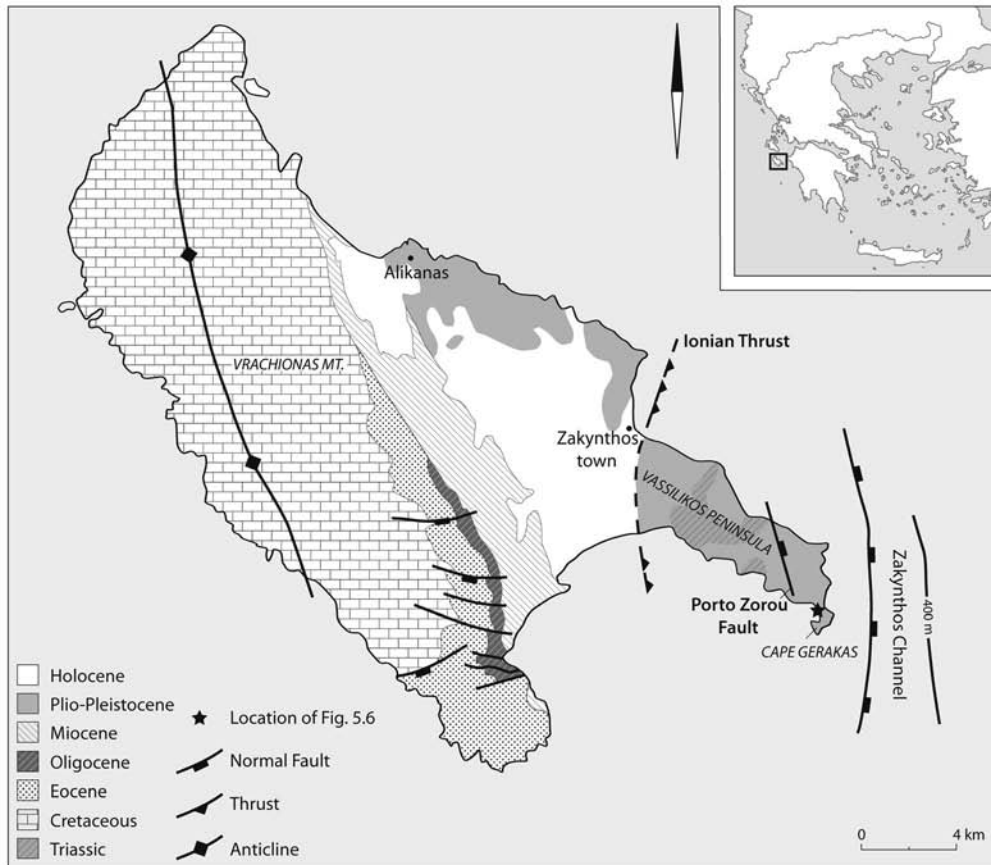


Fig. 5.5 Geological map of Zakynthos. Modified after Zelilidis *et al.* 1998

Alikanas basin) are now buried by Holocene deposits, whilst those that would have been overlying the Miocene deposits directly adjacent to the east of Vrachionas, have been uplifted, tilted and eroded into the Alikanas basin.

In the area between Zakynthos town and Alikanas, the exposures include Pliocene and Early Pleistocene marine sediments (Dermitzakis *et al.* 2000). During a reconnaissance visit of the area together with Prof. R. Caputo (University of Ferrara), we observed red sediments locally overlying the Plio-Pleistocene formations. However, this area is not included in the ZAP study-areas and it was not surveyed; in any case, those uppermost red layers occur only patchily and this is probably why they have not been mapped yet. Most likely, they are terrestrial sediments of late Pleistocene age, and future investigations can check if they contain any artefacts. The peninsula of Vassilikos is the area that has yielded most of the lithic

artefacts collected in the past (Sordinas 1970; Kourtesi-Philippakis 1999) and it also comprises the ZAP study-area with the largest densities in terms of lithic material. Five Formations (Fm), all separated by unconformities, have been defined in the local lithostratigraphic scheme: the Akra Davia Fm is of late Pliocene age, the Gerakas Fm spans the Pliocene-Pleistocene boundary, and the Kalogeras, Porto Roma and Ag. Nikolaos Fm's belong to the middle Pleistocene (Dermitzakis *et al.* 1979; *cf.* Zelilidis *et al.* 1998). Except for the lower part of the Gerakas Fm (which is of Late Pliocene age), all Formations appear to consist of marine deposits, as it is suggested by their sedimentological composition and the presence of marine fossils, and only some locally restricted sedimentary facies of the Porto Roma Fm are recognized as lagoonal sediments (Zelilidis *et al.* 1998). Abrupt transitions from thick mudstones to massive tidal sandstone sequences have been interpreted as the result of eustatic sea-level changes,



Fig. 5.6 Terrestrial deposits (Porto Zorou Fm?) unconformably overlying marine bluish-grey clays (Gerakas Fm), as exposed at the NW part of Cape Gerakas. Inset: detail showing a stratified flake projecting out of the terrestrial deposits

which are superimposed on the effects of subsidence along the Porto Zorou (PZ) fault (*ibid*, 402). The latter was probably the dominant fault associated with the subsidence of the Zakynthos Channel basin in the latest Pliocene; the Late Pliocene-Early Pleistocene Gerakas sediments were deposited in the hanging-wall of the PZ fault, which marked the western margin of the Zakynthos Channel (Zelilidis *et al.* 1998). At some point in the middle Pleistocene, a new master fault is formed, defining the present western boundary of the Zakynthos Channel; the area that was previously the locus of (marine) sedimentation as the down-thrown block of the PZ fault becomes now uplifted and back-tilted as part of the footwall of the new master fault; as a result, marine sedimentation is terminated (*ibid*). Then, from the middle Pleistocene onwards, non-deposition and erosion prevailed in the area due to progressive uplift.

The only (Pleistocene) terrestrial sediments in the area are the 7-m thick mudstones of the late Pleistocene Porto Zorou Fm. The latter was defined by Zeli-

lidis *et al.* (1998) and it is not mentioned in the publications of researchers who visited the area previously. In 2006, I examined a profile at the north-western part of the Gerakas Cape and I suggested that these sediments could be correlated with the Porto Zorou Fm (see Van Wijngaarden *et al.* 2007), because it fits the description of Zelilidis and colleagues and it is the only profile in the area of the Cape where terrestrial sediments crop out. These sediments (hereafter referred to as Porto Zorou Fm, even if the suggested correlation is not yet securely verified) rest unconformably over the bluish marls of the Gerakas Fm and the boundary of the two formations is marked by a sandstone layer (an observation that is in accordance with Zelilidis *et al.* 1998). The exposed profile is ca. 6 m thick and consists of clayey silts and sands in the lower part and more sandy layers in the upper, ~1, 5 m-thick part, capped by a thin topsoil; organic remains, manganese concretions and thin gravel lenses are also present in some of the layers (*cf.* Storme 2008 for more detailed descriptions). In 2006, I collected a few, isolated flint

artefacts projecting out of the upper part of the profile; during a revisit in 2007, another flake was found embedded in the lower part of the exposure (Fig. 5.6: inset). In both occasions, it was difficult to conclude whether the artefacts were definitely *in situ* in the deposits, or they have been washed down from higher points and were later covered again because of the ongoing erosion. Patinated artefacts of Middle Palaeolithic morphology and implements diagnostic of the Bronze Age were found in significant numbers on the surfaces of two morphological terraces that are cut on the upper part and on top of the Porto Zorou Fm. Another morphological terrace forms the ‘foot’ of Cape Gerakas in the southernmost part of the area; many flint artefacts, including probable Mousterian pieces, have been collected from the surface of this terrace. So far, it has not been possible to assess if there is any morphogenetic relationship between the red sandy soil covering this latter terrace with any of the layers (notably the uppermost) of the Porto Zorou Fm as it is exposed in the profile discussed above. Further research may test the hypothesis that Middle Palaeolithic artefacts are being eroded out of the sediments of the Porto Zorou Fm, and whether any of the observed terraces could be attributed to any of the sea-level high-stands of MIS 5.

Elsewhere in the Vassilikos peninsula the possibilities of finding stratified lithic artefacts are restricted to paleosol and ‘red-bed’ exposures that are extremely patchily preserved mostly in the centre and north-eastern part of the area. Sordinas (1970) reports the presence of heavily patinated and weathered flint artefacts associated with red-beds, which he identified in a restricted area of three km²; he observed that the redbeds are covered by fossilized dunes, which yielded Bronze Age artefacts. Sordinas does not provide any map and it was not possible to locate the exact area that he describes. Nevertheless, artefacts embedded in red sedimentary facies of terrestrial origin (and most likely of Late Pleistocene age) were identified during my visits in the area, but these are very exceptional and isolated occurrences; due to the severe erosion and deformation of soils and sediments in Zakynthos, they need to be further examined in test trenches, in order to confirm their *in situ* character.

Erosion in Zakynthos is vigorous. Due to the highly active tectonic setting, it may have been so already from the Pleistocene, but it has been certainly accelerated lately by anthropogenic causes: the current ever-growing and uncontrolled tourist development has resulted in widespread disturbance of Quaternary landforms. Geomorphological and soil erosion studies carried out in the framework of ZAP (Storme 2008; Gkouma 2009) have confirmed the destructive effects of past and present erosion upon the archaeological record. In contrast to the interior plains and the coastal areas, which are overall highly disturbed by cultivation and building operations, karst plateaus are good examples of relatively stable geomorphological settings, where artefact scatters can be found undisturbed. For instance, quite a large number of Palaeolithic artefacts have been collected from a gently undulating plateau on Mt. Vrachionas. The flat surface of the plateau and the fact that there are not any other adjacent landforms at a higher altitude precludes the possibility that the artefacts come from a derived context; rather, it can be securely concluded that the finds at this site are *sensu lato in situ*, *i.e.* they were originally discarded on the surface of this plateau. Most probably they are not archaeologically *in situ sensu stricto*, in the sense that we do not find them today in exactly the same place where hominins discarded them. However, the minimum-to-zero inclination angles of the surface, and the absence of traces of running water (in the form of gullies or streams) offer good reasons to assert that any movement of artefacts must have been minimal, and this conclusion is also supported by the preservation conditions of the specimens. However, the plateau represents a stable surface in the landscape, an exposed landform on which humans might have been making, using and ultimately discarding their stone-tools during any time within the Palaeolithic period, up to modern times. Accordingly, the lithic assemblage could be (or, *is indeed*) a palimpsest -a mélange composed of material belonging to different periods of the Palaeolithic.

On the current scarce evidence at hand, flint appears to have been the prevailing raw material for the production of stone tools in Zakynthos. As it is attested at least by the material from Vassilikos (Sordinas 1970; Van Wijngaarden *et al.* 2007), natural flint sources that seem to have been widely used are flint

pebbles from river valleys and beach deposits (*cf.* Van Wijngaarden *et al.* 2007). The original pebbles used as blanks are commonly small-sized and this fact poses another difficulty: the size and form of the raw material would not have favored the manufacture of large cutting tools, such as the characteristic handaxes and cleavers of the Acheulean techno-complex. Moreover, possible choppers and chopping-tools of 'Mode 1' toolkits cannot be morphologically distinguished from, for instance, the Mesolithic 'galets aménagés' (*cf.* Sordinas 1970). Hence, if bifacial products are expected to be scarce in the first place, even the problematic task of identifying Lower Palaeolithic artefacts based on morphological criteria, is further hampered in the case of the Zakynthos material.

To sum up, all formally defined and mapped Early and Middle Pleistocene sediments in Zakynthos are of marine origin; the possibility of finding stratified artefacts in these deposits is minimal. The only Pleistocene terrestrial sediments, *i.e.* the Porto Zorou Fm and patches of red sediments in the area of Vassilikos and to the NE of Zakynthos town, are most probably of Late Pleistocene age and are extremely restricted in both thickness and aerial extent. This explains why Early and Middle Pleistocene archaeological material is overall missing, whereas Late Pleistocene lithic artefacts are so far being collected mainly as surface finds. Moreover, erosion has significantly distorted the archaeological record, largely irrespective of the cultural periods at stake (Van Wijngaarden *et al.* 2006; 2007; 2009). As a result, scatters mixed with artefacts from different periods are the norm, rather than the exception, and in most cases these are erosional palimpsests. Stable areas like the plateaus on the karst terrain of Mt. Vrachionas, or those of the Vassilikos peninsula could potentially offer better insights, but contextual problems are present here as well: in such settings, artefacts may be *sensu lato in*

situ, but the mixing cannot be ruled out, this time in the form of accretional palimpsests. Caves and rock-shelters may, in theory, be devoid of such issues, and they offer themselves as potential targets for future investigations.

In conclusion, Zakynthos exemplifies all aspects of landscape dynamics that disturb the archaeological record and obscure any spatio-temporal distributions of artefacts and sites: a highly active tectonic setting, with thrusting, folding and normal faulting deforming and dislocating landforms; a tectonic and eustatic control promoting marine over terrestrial sedimentation during the Early and Middle Pleistocene; and an intense land use (and misuse) that has disturbed and destroyed most parts of the geological record that may have escaped natural erosion. All in all, the geological opportunities for the preservation of the archaeological archive are so limited that the inability of archaeologists to relate their findings to sedimentary contexts emerges as a wider reality, which largely overprints research-related biases. It should be noted, however, that the methodology of survey projects such as the ZAP (*i.e.* with a diachronic research objective), is not well-equipped for the recovery of Palaeolithic finds and their potential correlation with geological contexts (*cf.* Runnels and van Andel 2003).

Although Zakynthos appears to be an extreme example of conditions disfavoring the preservation of archaeological material, the factors and processes creating this picture apply to most of the landscapes in Greece, albeit in varying degrees. It is to those geomorphic and anthropogenic factors and processes that we shall turn in the following chapter, by broadening the scale of analysis so as to encompass Quaternary landscape evolution and its effects on the Pleistocene archaeological record of Greece.

6 – Quaternary landscape evolution and the preservation of Pleistocene sediments

6.1 INTRODUCTION

The landscape of Greece has long been used as a natural laboratory where prominent scholars from various disciplines of Earth Sciences and Humanities applied and tested their models, developed theoretical frameworks and elaborated on different methodological approaches. The Aegean Sea and its surrounding areas comprise one of the most rapidly deforming parts of the Alpine-Himalayan belt, and as an active tectonic setting it has contributed profoundly to resolving fundamental issues in structural geology and plate tectonics, hydrogeology, geomorphology, and many other subfields of geology (*e.g.* McKenzie 1978; Le Pichon and Angelier 1979; Leeder and Jackson 1993; Jackson 1994; Bell *et al.* 2009). Tectonic activity restricted the development of broad alluvial reaches in Greece (Macklin *et al.* 1995). Coupled with a markedly seasonal climate, this configuration resulted in the development of a landscape which does not promote extensive ecological zonation. The prevalence of mosaic environments, with a striking diversity and variety of ecological resources over short distances, has attracted the interest of ecologists and biogeographers (*e.g.* Tzedakis *et al.* 2002b; Medail and Diadema 2009). Major researchers working in the field of Palaeolithic studies and/or Landscape Archaeology were soon to appreciate the opportunities that this highly ‘broken-up’ geographical setting offers for the unraveling of key aspects in human-environment relationships. For example, Higgs and Vita-Finzi developed the method of site-catchment analysis during their work in the rugged relief of Epirus, initiating a long-lasting tradition of ecological/landscape approaches in the study of hunter-gatherer economy, which draws much attention to the topographical and geomorphological attributes of the landscape (Higgs and Vita-Finzi 1966; King and Bailey 1985; Bailey *et al.* 1993; Bai-

ley 1997). Despite the major contributions from geological and geographical investigations, and notwithstanding this rather early interest by archaeologists in the role of the landscape, the latter was for a long time conceived essentially as a static, inexorable background that needs to be solely reconstructed in order to become the setting for the archaeological narrative. In this respect, it is only recently that researchers have been encompassing a more integrated and holistic perspective of landscape development in the frames of Palaeolithic investigations (*e.g.* Runnels and van Andel 2003).

Although the role of climate, erosion and tectonic movements was stressed already by the first pioneering researchers (*e.g.* Higgs and Vita-Finzi 1966; King and Bailey 1985), it was only later that an emphasis was given to such factors as agents of bias in the formation of the geoarchaeological archive (*e.g.* Bailey *et al.* 1992; Runnels and van Andel 2003). Inevitably, such a discourse was bound to be focused on and restricted in the spatial and temporal frames defined by each project’s objectives. It was basically a combination of research biases (*e.g.* research models targeting primarily caves and rockshelters until about the 1980’s; Runnels 2003a), the lack of robust environmental data sets and the limited evidence from excavated sites that hindered the development of broader syntheses with respect to Quaternary landscape evolution.

In this light, the following chapter aims to contribute to the understanding of landscape evolution in Greece during the Quaternary and how this might have influenced the geological and geomorphological opportunities for preservation of Lower Palaeolithic material. Needless to say, the temporal and spatial scale for such an endeavor does not allow for proper modeling. It does allow, though, for a critical

overview of the main aspects of climatic fluctuations, tectonic activity, sea-level changes and slope processes, as well as the associated geomorphic controls imposed by those four principal agents of landscape change. The explorative and/or speculative nature of some parts of this treatment is believed to be justified by the apprehension that the aim has first and foremost an archaeological origin: in this regard, rather than high-resolution patterns, it is highly robust ones that are sought.

All in all, the geomorphological perspective advanced here in order to assess past, actual, and potential effects of geomorphic processes upon archaeological preservation and visibility, serves primarily as a starting point for:

1. evaluating the existing status of the Greek Lower Palaeolithic record, with regard to the issue of 'absence of evidence' or 'evidence of absence',
2. understanding and anticipating geomorphic biases, and
3. developing analytical tools and models for future investigations

The critical examination of the Greek 'Lower Palaeolithic' evidence (chapter 4) demonstrated that the record of Greece is in marked contrast to those of other circum-Mediterranean areas (chapter 3), in its main quantitative and qualitative characteristics: there are very few sites and there is an overall lack of stratified material. The fact that a large portion of the evidence lacks a stratigraphic context and/or is associated with secondary contexts emerges as a wider pattern that cannot be attributed to inappropriate research designs, the intensity of investigations or a lack of specialists in the field, as was discussed above in chapter 5. The exploration presented below assesses whether this general 'absence of (stratified) evidence' could be ultimately regarded as 'evidence of absence' for archaeologically visible hominin activities. The remains of these activities are likely to have been preserved, accessible/visible and stratified until the present only in areas where the relevant geological record is equally complete enough and has remained largely undisturbed. Disturbance versus preservation, erosion versus deposition, and deposition/preservation versus archaeological visibility/accessibility, are all conditioned mainly by geomorphic factors. These factors and their potentially biasing effects upon the

archaeological record are tightly interrelated but are examined here as separate as possible, into four major groupings: climate, tectonism, sea-level changes and surface (slope) processes. When viewed in conjunction (section 6.6), a conclusion can be drawn on how geomorphic processes have shaped the available geological opportunities, which in turn configured the nature and extent of preservation of the archaeological record.

On this basis, we can arrive at both a quantitative and qualitative assessment of the current picture: how much of the archaeological record may have been lost compared to the geological record at our disposal, how much of it is likely to have escaped the biasing geomorphic agents and what kind of geoarchaeological contexts are we facing today and we should expect to deal with in the future. In this sense, the results of this exploration do not only touch upon the evaluation of the evidence at hand, but also anticipate future research and the methodological toolkit that we need to develop in dealing with geomorphic biases. Despite the fact that the landscape of Greece has attracted early on the interest of earth-scientists and archaeologists, the literature so far lacks a synthesis of landscape evolution in Greece during the Quaternary; it is hoped that the following lines will contribute in filling this vacuum, even if the perspective here remains essentially an archaeological one.

6.2 CLIMATIC CONTROLS

"If tectonics and lithology favor erosion, the main determinant of when it happens is weather" (Grove and Rackham 2001)

6.2.1 The climate of Greece

Greece has a Mediterranean climate,⁴² namely one with hot, dry summers and mild, humid winters, where winter rainfall is at least three times more than

42. As a result of the interactions within a mosaic of environmental processes and ecological responses between biotic and abiotic factors at a wide range of spatial and temporal scales, the climate of the Mediterranean displays a vast diversity of features and hence a variety of climate sub-types (Allen 2001). There are, however, general characteristics which are common in the entire basin. In that sense, the general term 'Mediterranean climate' is

that of the summer. As the Mediterranean basin is situated within the boundary between subtropical and mid-latitude atmospheric patterns, its climate is particularly sensitive even to minor changes of the general circulation (Berger 1986), for instance shifts in the location of the mid-latitude storm tracks or sub-tropical high pressure cells (Giorgi and Lionello 2008). Such shifts are thought to be partly responsible for the Quaternary climatic fluctuations and the related changes in the seasonality and geographic distribution of precipitation (Macklin *et al.* 1995). Pressure conditions are markedly contrasted between the western and eastern parts, with the latter being affected mainly by the South Asian monsoon and the Siberian High Pressure System (Xoplaki *et al.* 2003). Thus, in terms of precipitation patterns, there is a broad contrast between double maxima of autumn and spring rainfall in the northern parts and a winter maximum in the southern, whereas the amount of rainfall and the duration of the rainy season decrease from west to east and north to south, with summer drought increasing in the same direction in both duration and intensity (Macklin *et al.* 1995). Interactions between different depression regimes result in unequal distribution of rainfall throughout winter, concentrated into a few days per month or season (Allen 2001). Summer drought lasts longer in the south-eastern parts, extending for up to five consecutive months. Drought is intensified by desiccating regional winds of continental tropical origin, such as those coming from Algeria and the Levant, whereas occasional monsoon air masses may promote summer rainfall.

The establishment of the Mediterranean climate (notably, with a seasonal precipitation mode and a predominantly sclerophyllous vegetation) occurred progressively around the end of the Tertiary and is associated with two major climatic changes. The first occurred at *ca.* 3.2 Ma and introduced a dry summer

season together with an increase in sclerophyllous taxa, whereas the second refers to the onset of Northern Hemisphere glaciation and global cooling (Suc 1984). Pollen records from southern Italy and Sicily indicate that significant latitudinal vegetational and climatic (*e.g.* thermal) gradients existed in the Mediterranean Basin already in the (late) Pliocene (Bertoldi *et al.* 1989); a longitudinal gradient was superimposed on the latter ones, reflecting the influence of the Asian monsoon (Suc and Popescu 2005). Other lines of evidence suggest that the Mediterranean climate may have been established intermittently during the course of the Tertiary, or even much before (Tzedakis 2007). In this light, ‘establishment’ does not mean ‘permanence’ (*ibid.*, 2059) and the bi-seasonality of the climate has not been consistent since that time, due to the Quaternary climatic fluctuations (Allen 2001). Hence, “Mediterranean conditions would appear during interglacials (reaching their maximum expression during boreal summer insolation maxima), but would not persist during glacials” (Tzedakis 2007, 2059).

The climatic signal in Greece is modulated inter-annually and inter-seasonally and at small spatial scales by the interactions of a complex topography and steep relief with altitude, latitude, orography, vegetational belts and proximity to the marine littoral. In general, western Greece is influenced by low pressures in the western Mediterranean and experiences an annual rainfall between 780 to 1280 mm, whilst eastern Greece is under the influence of the Siberian anticyclone with rainfall amounts ranging between 380-640 mm per year (Kosmas *et al.* 1998a, 71). If we consider also the highest altitudes, such as the uplands of Epirus where precipitation may be >2500 mm, then the decrease in precipitation moving south-east from northwest may be up to tenfold (Fig. 6.1). Most rainfalls occur between October and March, whereas from May to October, potential evapotranspiration exceeds rainfall, creating a large water deficit for plant growth. Average air temperature ranges from 16.5° to 17.8° C. During the cold period, temperature increases with decreasing latitude, while in the warm period temperature increases from the coast to the mainland and especially the plains (*ibid.*). According to the bioclimatic classification of the xer-

used in this chapter to describe patterns that are also applicable to Greece. Similarly, descriptions referring to the ‘south-eastern Mediterranean’ should be considered as denoting principles that again apply to the climate of Greece, if the latter is not explicitly stated. As the focus is on Greece and the Mediterranean basin, ‘Mediterranean climate’ refers to that of regions inside the Basin and not to Mediterranean-type climates of other places in the globe (often called ‘Mediterranoids’).

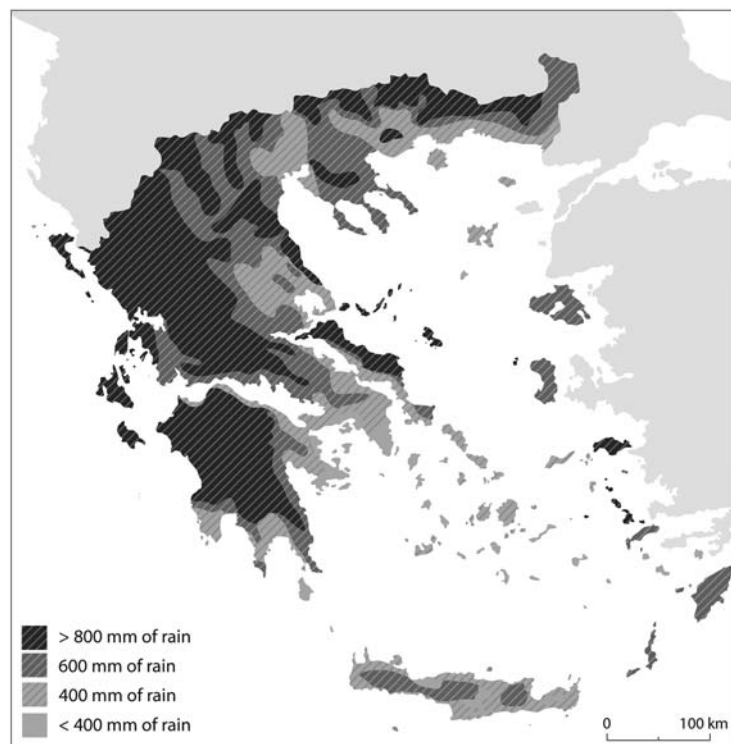


Fig. 6.1 Distribution of annual precipitation in Greece. Modified after Kosmas *et al.* 1998a: fig. 5.3

othermic index⁴³, most parts of Greece have a meso-mediterranean climate, attenuated (*i.e.* shorter dry season) from the Albanian coast inland, over the middle latitudes of north Greece and the Peloponnese, and accentuated (*i.e.* longer dry season) in the lowland and coastal areas (Tselepidakis and Theodoratos 1989)

6.2.2 Climate, weathering and surface processes

Langbein and Schumm (1958) studied the climatic control on fluvial denudation rates by comparing the sediment yield of drainage basins located in a variety of climates; they found that sediment yield increases with effective precipitation to a peak (at *ca.* 300 mm) followed by decline. The relationship between precipitation and erosion becomes complex and non-linear due to the influence of vegetation (Bloom 2002, 339; Jiongxin 2005). Erosion intensity depends (*inter alia*) on rainfall erosivity and the erosion-resistance capacity of the land. The latter is largely controlled

by soil physico-chemical characteristics and land cover properties. Apart from lithology and grain size, there are many soil properties (*e.g.* aggregate cohesion and stability, moisture and organic matter content, porosity, bulk density, etc) and pedogenic processes that are in turn influenced by vegetation (Rettallack 2001). Vegetation cover protects the soil from erosion by the combined effects of various mechanisms: it protects the soil from rain-splash impact and crusting; canopy and litter intercept raindrops, reducing rainfall kinetic energy; organic matter builds up in the soil increasing soil moisture, which in turn enhances aggregate stability; the plant root system binds the soil together; vegetation adds to surface roughness, reducing overland flow velocity (Kirkby 1999; Casermeiro *et al.* 2004). Vegetation patterns are closely associated with the amount and temporal distribution of annual precipitation; generally, higher annual precipitation results in denser vegetation cover and higher vegetation biomass. Hence, in arid/semi-arid conditions, erosion increases as precipitation increases up to a threshold, because precipitation is still inadequate to maintain an effective vegetation cover; beyond that threshold, further increase in precipitation increases vegetation cover to the degree that the latter is now able to enhance

43. This index is the sum of the calculated indices for the dry months and provides the number of biologically dry days during the drought season (UNESCO-FAO 1963).

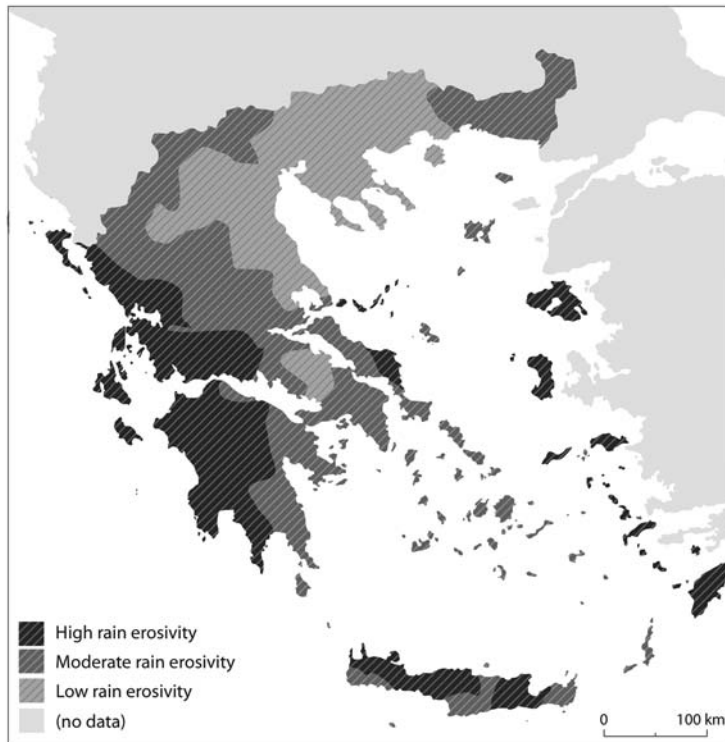


Fig. 6.2 Rain erosivity map of Greece, modified after Kosmas *et al.* 1998b: fig. 15.2. Areas of 'high rain erosivity' experience rainfalls that are unevenly distributed throughout the year; they commonly come in the form of intense storms of short duration and occur during dry seasons

soil stability and the erosion-resistance capacity of the land surface.

For a wide range of environments, both runoff and sediment loss decrease exponentially as the percentage of vegetation cover increases, and if the latter falls below a value of 40%, then, accelerated erosion dominates in sloping lands⁴⁴ (Kosmas *et al.* 1999b, 26). For the Mediterranean, the main climatic attributes controlling the degradation of landscapes, especially in semi-arid and arid zones, are the uneven annual and interannual distribution of rainfall, the extreme rainfall events and the out of phase of rainy and vegetative seasons (*ibid.*, 19; Fig. 6.2).

Grove and Rackham argue (2001, 247) that water-related erosion in the Mediterranean depends chiefly on deluges rather than ordinary rainfall. They stress that a single deluge can be expected to have erosional consequences greater than that of ten separate falls of 10-mm-rain. With regard to fluvial erosion, a minor deluge is able to increase a river's sediment

load to at least twice as much material, occasionally twenty times as much in the month of the deluge as in the rest of the year (*ibid.*). Importantly, when such extreme events occur early in the season and plant cover is minimal, gullying and sheet erosion is promoted, whereas, late in the season, soils may have now acquired the saturation levels necessary to trigger slumping. Hence, rather than the quantity of the rain, it is pulses of high intensity within storms, which determine the erosional effect⁴⁵ (Grove and Rackham 2001, 251). Such intense blasts of rain generate high turbulent surface runoff and are influenced by topography and wind gustiness. Consequently, notwithstanding the importance of a number of feedback-mechanisms between climatic erosivity and soil erodibility, the dominant influence of erosion is the precipitation input, particularly as a result of extreme events (Mulligan 1998).

44. Macklin and colleagues place this threshold of vegetation cover at 70% (1995, 12).

45. Results showed that falls of more than 40 mm accounted for up to two thirds of the erosion, even though they comprised less than 5% of rainfall events and provided little more than 20% of the total rain (Grove and Rackham 2001, 251).

The effects of soil texture and depth, parent material, topography and climate on vegetation performance and degree of erosion were studied at the island of Lesbos (NE Aegean Sea, Greece), along three climate zones: 'semi-arid', 'transitional' and 'dry sub-humid' (Kosmas *et al.* 2000). Soils of the same parent material become deeper from the semi-arid zone towards the sub-humid zone, and for all climate zones, vegetation cover increases with soil depth, whereas both vegetation and soil depth are positively correlated with increasing rainfall (but see also Mulligan 1998, 76). Under an annual rainfall of between 550-800 mm, runoff from grass or bare surface may be 120 mm greater than from forest, but trees may have less effect on the torrential rains that do most of the erosion, and many studies concur that maquis, tall undershrubs and grassland are at least as effective as forest (Grove and Rackham 2001). There is evidence that olive trees minimize the speed and amount of runoff, even under extreme rainfall events (*ibid.*, 263), whilst scrublands are the most common plant communities in eroded areas of the Mediterranean (Casermeiro *et al.* 2004).

In another comparative project, the effects of land use and precipitation on runoff and sediment loss were studied at eight Mediterranean sites (Kosmas *et al.* 1997). The results showed that the sites with olives grown under semi-natural conditions gave the lowest rates of runoff and sediment loss. Interestingly, under shrubland vegetation cover, both sediment loss and runoff increase with decreasing precipitation as long as the latter exceeds *ca.* 300 mm per year; below this threshold, erosion decreases with increasing aridity (*ibid.*, 57). Noteworthy, the value of 300 mm precipitation corresponds well to the threshold of the Langbein-Schumm (1958) curve and to that reported by Lavee *et al.* (1998), whereas Inbar (1992) also showed that, although it has been questioned by other studies, the general trend predicted by Langbein and Schumm is valid for basins with a Mediterranean-type climate.

6.2.3 Quaternary climate changes in Greece

There are many interrelated factors that hinder precision in reconstructing Quaternary climate fluctuations and the responses of terrestrial ecosystems to

those changes. Some of the main issues concern the following points:

1. Relationships between climatic manifestations such as insolation, temperature and ice volume appear to be non-linear and/or disproportional, due to a number of feedbacks, leads and lags in the earth system; this recent appreciation could even challenge the Milankovitch theory of astronomical climate forcing (Roucoux *et al.* 2008; Maslin and Ridgwell 2005). Equally complex is the task of deciphering the imprint of climate oscillations upon terrestrial records, especially as regards the highly dynamic ecosystems of the Mediterranean; for instance, steep environmental gradients and spatial heterogeneity may result in disparate records of ecosystem change, *e.g.* from pollen-cores deriving from catchments in close proximity to each other, thus impeding a straightforward interpretation of pollen diagrams (Allen 2003). Comparisons may be similarly problematic between different land-records.
2. Continuous terrestrial sedimentary sequences spanning consequent glacial-interglacial cycles are rare due to hiatuses in sedimentation, sedimentary rate changes and lateral variability (Ehlers and Gibbard 2003).
3. Different sets of data record climatic signals of a variety of time-transgressive processes that operate in a range of spatial and temporal scales. As a result, it is difficult to disentangle causal, amplitude- and phase-relationships between the marine, ice-core and continental records (*e.g.* Tzedakis *et al.* 2001; Kukla *et al.* 2002; Tzedakis 2005).
4. All of the above associations are further complicated by divergences in the sensitivity of records and quality of resolution, which are coupled by disparities in the precision of chronological controls and the positioning of chronological anchor points. Whereas there is a relative plethora of evidence for the climate changes of the Late Pleistocene, the events preceding the Last Interglacial can be only broadly reconstructed (*e.g.* Macklin *et al.* 2002), and the discrepancies between continental and deep-sea chronologies increase for the older parts of the Quaternary (Ehlers and Gibbard 2003).

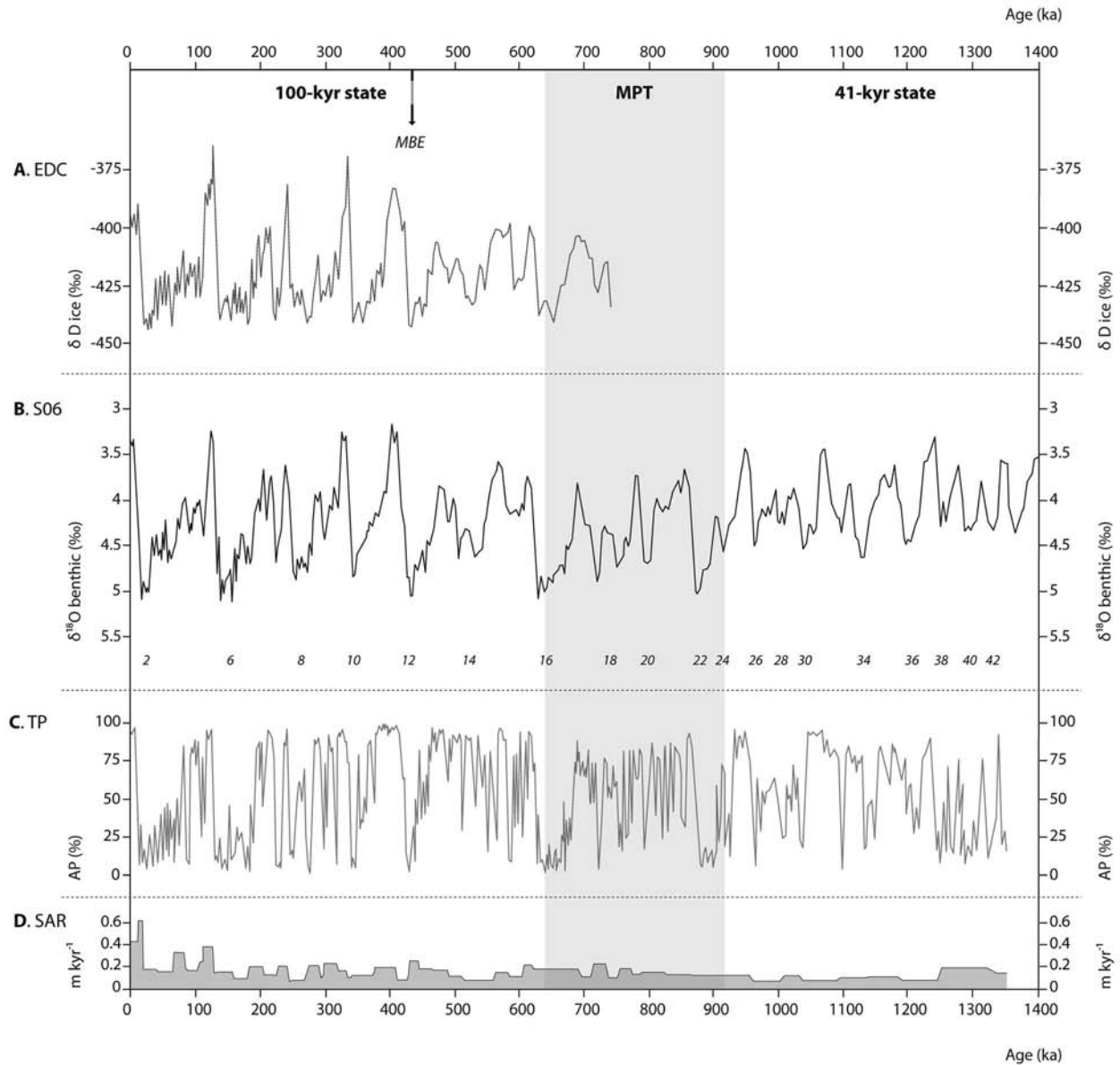


Fig. 6.3 The Tenaghi Philippon Arboreal Pollen (AP) curve (C) plotted on the pollen-orbital derived timescale and compared to (B) the S06 $\delta^{18}\text{O}$ benthic composite record from sites in the equatorial East Pacific and (A) the EPICA Dome C Deuterium (δD) record from Antarctica. Glacial marine isotopic stages, sediment accumulation rates (D), the mid-Pleistocene transition (MPT) and the position of the mid-Brunhes event (MBE) are also indicated. Modified after Tzedakis *et al.* 2006: fig. 5

Early Pleistocene glacial cycles follow a pace of 41,000 yr-duration attributed to the earth's obliquity, whilst Middle and Late Pleistocene cycles have a 100-ka timescale accredited to orbital precession (Maslin and Ridgwell 2005). The change in the mode of climatic variability is known as the 'mid-

Pleistocene transition/revolution' (Fig. 6.3) and is thought to be significant in terms of differences between the two periodicities in the magnitude and amplitude of climatic effects (*e.g.* EPICA 2004; Head and Gibbard 2005), although the nature and mode of the transition has recently been questioned (Huyberts

2007). It is clear though that this change marks a significant increase in global ice volume, the onset of the most extensive glaciations in the Quaternary (beginning with MIS 22) as well as a transition from linear to non-linear forcing of the climate system (Head and Gibbard 2005). Whilst this shift is generally centered at around 800-900 ka, another distinct climatic change, the 'mid-Brunhes event', roughly corresponds to the transition between MIS 12-11 at *ca.* 430 ka (EPICA 2004). This latter transition is viewed as resembling the one into the present interglacial (although longer and with marked differences in the pattern of change) and MIS 11 not only defines a boundary between two different patterns of climate (*ibid*), but is also considered a unique and exceptionally long interglacial, which may be the best analogue for the present climate (Loutre and Berger 2003; Raynaud *et al.* 2005; but see also Helmke *et al.* 2008).

Whereas climatic variability on orbital frequencies is now well-known, research on the last glacial period has shown that rapid climatic fluctuations occurred on suborbital (millennial-centennial) timescales (*e.g.* McManus *et al.* 1999; Alley *et al.* 2003). High-resolution lake sediment data from Italy and from a marine core in the Ionian Sea demonstrate that the North Atlantic climate variability extended its influence as far as the Mediterranean, also with regard to those high-frequency oscillations, to which vegetation communities responded equally rapidly (Allen *et al.* 1999). Correlations of terrestrial records to marine data sets, either directly through joint pollen studies and oxygen isotope analyses on foraminifera from the same marine core (Roucoux *et al.* 2006; Desprat *et al.* 2009); or indirectly, when assigning the marine timescale to terrestrial sequences by assuming synchronicity of certain events (and using glacial-to-interglacial transitions as tie-points; Tzedakis *et al.* 1997), provide evidence for a close connection between continental and marine records in terms of both orbital and suborbital variability (Tzedakis *et al.* 2006). For the linking of the records, another approach is the pollen-orbital tuning procedure, where palynological changes detected in Mediterranean cores (including Ioannina and Tenaghi Philippon, Greece; see below) are compared directly with astronomical curves (Magri and Tzedakis 2000; Tzedakis *et al.* 2006). For instance, comparison of the Tenaghi

Philippon pollen curve with marine sequences (*e.g.* Fig. 6.3) showed that, on orbital frequencies, ice volume extent correlates well with tree population size, whilst on suborbital scales the land-record shows similar frequencies of peaks in steppe vegetation and North Atlantic ice-rafting events (Tzedakis *et al.* 2003b; 2006). Overall, a broad equivalence of terrestrial and marine signals has been confirmed, and the marine isotope stratigraphy can be seen as an appropriate framework also for viewing the continental record (Tzedakis *et al.* 2001, 1585). It is in this respect -and by acknowledging that marine and terrestrial boundaries may not be precisely synchronous- that the marine nomenclature ('MIS') is retained here even when referring to terrestrial stages and/or biogeographical events (*e.g.* forest expansion/contraction).

As indicated by pollen data from South European sites with sufficient moisture, an idealized scheme of vegetation phases within a glacial-interglacial cycle entails the following stages (Tzedakis 2007): a pre-temperate phase of open woodland, with expansion of pioneer taxa (*Juniperus*, *Pinus*, *Betula* and *Quercus*); a temperate phase with the development of Mediterranean forest/scrub communities (warm and dry conditions), deciduous forest (warm and wetter) and montane/coniferous forest (beginning of cooling); then, a post-temperate phase of open woodland (initial cooling and drying), followed by the onset of glacial steppe vegetation (cold and dry conditions). Although temperature is an important parameter (mostly for upland and northern areas), the critical climate factor behind these shifts in vegetation composition is considered to be changes in precipitation (Woodward *et al.* 1995).

Long and continuous Quaternary sedimentary sequences in Greece are typically to be found in intermontane basins, usually of tectonic origin (Mountrakis 1985). Thus far, the best-studied polleniferous lacustrine sediments have been retrieved from three such basins (see Fig. 4.1 for their locations): Ioannina, in north-western Greece, provided a high-resolution record (*i.e.* the latest core, I-284, with a mean sampling interval of 200 years) extending back to *ca.* 450 ka (Tzedakis 1994); Tenaghi Philippon, in north-eastern Greece, has the longest continuous European pollen record, with the base of the sequence extend-

ing back to 1.35 Ma (Tzedakis *et al.* 2006); and Kopaïs, in central-eastern Greece, contains a record that extends into the last interglacial and up to MIS 11 (Okuda *et al.* 2001).

Interglacials and interstadials

During the past one million years, interglacials had an average duration of about half a precession cycle, namely *ca.* 10.5 ka (strictly speaking, that is for their warmest and least variable parts; Tzedakis 2007; Kukla *et al.* 2002). Evidence from the Greek and other Southern European records suggests that the onset of interglacial forest expansion is more closely associated with the timing of summer insolation peak and is less influenced by the timing of deglaciation, provided that there is no significant residual ice volume (Tzedakis 2005, 1589). Noteworthy, for the early part of interglacials coeval with boreal summer insolation maxima, palynological evidence indicates enhanced summer aridity, while isotopic data from speleothems point to increased rainfall (Tzedakis 2007). An explanation for this discrepancy argues that this excess precipitation may have come in the form of severe storm events. In turn, these events may have increased moisture, but would not add much to soil moisture availability for plant growth, as most of the water would have been quickly removed as fluvial runoff (*ibid.*).

In contrast to the evidence from other records (*e.g.* the ice-core record from Antarctica, EPICA 2004) in which interglacial maxima appear significantly cooler before the Mid-Bruhnes Event (MBE) than post-MBE maxima, the amplitude of interglacials in the Tenaghi Philippon (TP) sequence does not show any considerable difference in the extent of tree population expansions of the various temperate stages (Tzedakis *et al.* 2006). For instance, both Arboreal Pollen (AP) maxima and the vegetational character of MIS 13 and 15 are similar to post-MBE interglacials. The TP-record suggests that the most floristically diverse interglacials occurred before MIS 22-24 and that most of the relict taxa were extirpated during MIS 16. Moreover, there is a major shift in the vegetational profile of interglacials after MIS 16, with forests of reduced diversity and a 'modern' appearance (*ibid.*). Consequently, a major vegetational change is associated with the MIS 16-15 transition, rather than

that of the Mid-Bruhnes Event (MIS 12-11 transition).

When comparing the TP and Ioannina records, a first conclusion to be drawn is that they display a marked degree of correspondence in the relative expansion and contraction of forest and open vegetation communities and a tripartite division into temperate sub-stages for the interglacial complexes of MIS 5, 7 and 9 (Tzedakis *et al.* 1997, 2003b). From the TP record, we see that during MIS 11, temperate AP values show peaks associated with substages 11c and 11a, with MIS 11b being dominated by *Pinus*. Within MIS 9, maximum forest expansion occurred during 9e, followed by 9a, with 9c displaying the lowest values (Tzedakis *et al.* 2003b). The MIS 7 interglacial complex shows broadly similar AP values for all three temperate intervals, but it is MIS 7c that had the longest duration and the most floristically diverse forest expansion, displaying also the highest insolation values within this complex and of the last 450 kyr (*ibid.*). Instead, during MIS 7e (*ca.* 239-237 ka) there was a shift to drier and cooler conditions which resulted in forest decline and a premature ending of the terrestrial interglacial across southern Europe (this is also evident in other records from France and Italy; Tzedakis *et al.* 2004b).

With regard to MIS 7, the results from TP have recently been supported by new pollen and sedimentological data with a centennial-scale resolution from Ioannina Lake (core I-284). Four forested intervals have been identified here, with similar percentages for temperate trees suggesting similar extents of tree populations (Roucoux *et al.* 2008). In the intervening periods, drier conditions are indicated by the predominance of open vegetation, where Graminae and semi-desert taxa (*Artemisia*, *Chenopodiaceae*) are abundant and specific trees and shrubs disappear, reflecting decreased temperatures; yet, throughout these periods, coniferous and temperate trees persisted, signifying survival of small populations. Whereas at Tenaghi Philippon trees almost completely disappeared during MIS 7d, at Ioannina they survived in abundance. The discrepancy between the two records is thought to reflect local conditions and climatic contrasts between north-western (Ioannina) and north-eastern (TP) Greece, with the latter experiencing drier and more continental conditions. Over-

all, during the temperate stages, summers were probably wetter and winter temperatures were most likely lower than those of the Last Interglacial and Holocene in NW Greece. At the beginning of MIS 7e and 7c, expansion of pioneer taxa indicates colonization of open habitats with immature soils, followed by deciduous populations as the climate warmed. This pattern indicates that parts of the catchment were previously de-vegetated, experiencing severe soil erosion during the cold intervals of MIS 8 and 7d, respectively (Roucoux *et al.* 2008, 1391). In contrast, there is no clear pioneer succession at the other two forested intervals (MIS 7a and post-7.1), indicating that soils which had developed during preceding warm periods were essentially maintained through the next stadials, remaining vegetated and resisting erosion. Sediment organic content increases two- to four-times more during the forested intervals and organic content peaks coincide with times of highest pollen concentration, which in turn indicates highest percentages of vegetation biomass. Peaks in magnetic susceptibility values match closely with reductions in vegetation cover and are thought to reflect soil inwash to the lake and increased erosion rates, whereas low values would correspond to low catchment erosion under continuous vegetation cover (Roucoux *et al.* 2008, 1392).

Episodic contractions of temperate tree populations in the Ioannina record, such as that of MIS 7d, indicate oscillations on suborbital time-scales. At the onset of substage 7e, climate warming was briefly interrupted, as it is suggested by a short tree-population contraction (*ibid.*). Such a reversal in forest expansion precedes also the onset of the last interglacial in the Ioannina record (Tzedakis *et al.* 2003a) and is manifested in the Portuguese marine core as well (Roucoux *et al.* 2006). Altogether, this data support the view that abrupt and short-lived climatic fluctuations originating in the North Atlantic were influencing Greece and have been a consistent attribute of transitions from cold to warm stages (Roucoux *et al.* 2008).

There is now growing evidence from Southern Europe pointing to abrupt events within interglacial complexes that are not accompanied by changes in ice volume (*e.g.* Brauer *et al.* 2007; Desprat *et al.* 2009). This in turn is reflected in a diachrony be-

tween terrestrial and marine stage boundaries, with temperate vegetation lagging changes in ice volume and sea level (Tzedakis *et al.* 2002a; Desprat *et al.* 2009). At Ioannina, the onset of the Last Interglacial is placed at *ca.* 127.3 ka, hence well within MIS 5e and after deglaciation was complete, whilst its end is at *ca.* 111.8 ka, indicating that terrestrial interglacial conditions persisted into the marine interval of MIS 5d (Tzedakis *et al.* 2003a), lagging *ca.* 5000 years after the building-up of ice volume. Whether such a diachrony between glacial inception and vegetation changes in southern Europe during the last interglacial was an attribute of earlier interglacials remains an open issue. Notably, as manifested in the Greek and other southern European records, a duration of *ca.* 15.5 kyr for the Last Interglacial is in contrast to estimates of *ca.* 10 kyr for the Eemian in Northern Europe (Turner 2002; Shackleton *et al.* 2003; but see also Kukla *et al.* 2002;), supporting the view of a prolonged interglacial duration in southern Europe (Tzedakis *et al.* 2004b; but see also Tzedakis 2007, 2060). For the early part of the Last Interglacial, pollen data show a peak in Mediterranean sclerophyllous taxa and oxygen isotope analyses from calcites indicate a decrease in the precipitation/evaporation ratio during the same pollen zone (Frogley *et al.* 1999, 1887); together, these proxies suggest a warmer climate with mild winters and drier summers (drought conditions). Mediterranean fluvial records indicate that this was a period of valley floor incision and soil development on stable terrace surfaces (Macklin *et al.* 2002). Comparison of last interglacial pollen evidence from Ioannina, TP and Kopais shows a general trend from mixed interglacial forests with high biomass to more open and less diverse forests, going from Ioannina to TP and Kopais (Tzedakis 2000). This variability reflects differences in climatic regimes that are also obvious in Greece today, hence suggesting similar spatial climatic patterns during the last interglacial (*ibid.*).

Before the onset of last interglacial conditions at Ioannina, the penultimate glacial maximum (*ca.* 133-129.3 ka) was characterized by relatively dry conditions with reduced precipitation and it was followed by an interstadial (*ca.* 129.3-128.0 ka) and a stadial (*ca.* 128.0-127.3 ka; Tzedakis *et al.* 2003a). Similarly, as it is attested also in TP and Kopais, the ending of interglacial conditions took place in a stepwise

fashion, with a pulse in the establishment of open vegetation followed by a short-lived reappearance of tree populations before the arrival of stadial conditions (*ibid*). Fluctuations occurred also within the interglacial proper in a series of subdued steps (Fig. 6.4), which were markedly smaller in amplitude and with a longer duration than the oscillations before and after the onset of full interglacial conditions (Frogley *et al.* 1999). The high-frequency and large-amplitude climatic shifts during the early and late part of the interglacial could be a reflection of rapid and severe events associated with ice-sheet decay/growth in the North Atlantic. On the other hand, for the interglacial proper, the subdued character of the oscillations may suggest that, during periods with minimum ice volumes, North Atlantic variability had a reduced influence on climatic conditions in Greece. In this latter case, the oscillations arise from responses to gradual changes in insolation, representing the crossings of environmental thresholds and “jumps” between preferred climate states: “climatic conditions would then remain quasi-stable with little vegetation overturn until the next threshold was crossed” (Tzedakis *et al.* 2003a, 165).

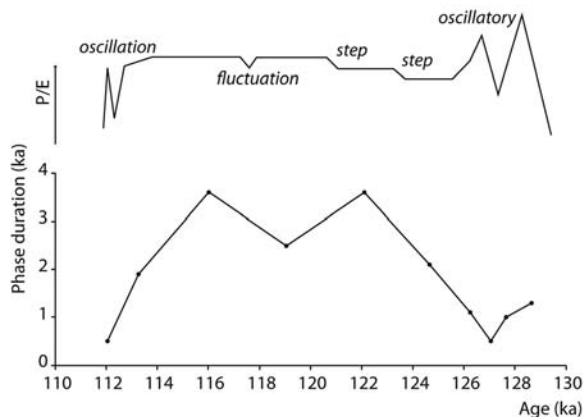


Fig. 6.4 Diagram showing climatic variability during 130-110 ka at Ioannina. Variations in the precipitation/evaporation ratio (P/E) are drawn on an arbitrary scale. After Tzedakis *et al.* 2003a: fig. 5

Suborbital climate fluctuations also characterize the Holocene (Mayewski *et al.* 2004) and, although generally weaker in amplitude than those of the last glacial cycle, many of these shifts occur rapidly (*i.e.* in a few hundred years or shorter; *ibid*), perhaps legiti-

mizing the view of the present interglacial as “a period of climatic instability” (Jalut *et al.* 2009, 13). Holocene climate variability indicates that quasi-periodic changes could be abrupt and profound even in the absence of the voluminous and unstable ice masses of the Pleistocene (Mayewski *et al.* 2004), manifesting a pervasive millennial-scale climate cycle that operates independently of the glacial-interglacial climate state (Bond *et al.* 1997). As elsewhere in the Mediterranean (Jalut *et al.* 2009), the early to middle Holocene in Greece is marked by increases in non-steppe herbaceous taxa and expansion of mixed deciduous woodland (Willis 1994), which were favored by wetter conditions, as it is indicated also by lake-level data (Digerfeldt *et al.* 2007). However, since moisture availability was the main controlling factor for reforestation, the latter was completed sooner at sites with abundant precipitation, such as Ioannina in western Greece, than in the northern borderlands of the Aegean and probably also at the surroundings of Lake Xinias and Lake Kopais in central-eastern Greece (Kotthoff *et al.* 2008). The general trend towards a warmer and wetter climate in the early Holocene was interrupted by short-term climatic deteriorations, and vegetation communities were subjected to repeated, centennial-scale setbacks, mirrored by decreases in arboreal pollen and occasional increases in steppic taxa, which probably reflect reduced moisture availability (*ibid*). One such abrupt deterioration at around 8.1 ka is thought to be correlative with the well known 8.2 ka cold event of the Northern Hemisphere (Alley and Ágústssdóttir 2005). The colder and drier conditions of this short interval are also recorded in the isotopic record of the Soreq Cave (Bar-Matthews *et al.* 1999) and it is possible that they correspond to a major erosional event in Theopetra Cave (Thessaly) and a stratigraphic gap in Franchti Cave (Argolid) as well, suggesting a broader impact on the caves of the area (Karkanas 2001). Aridification was gradually intensified during the mid- and late Holocene, culminating at around and after *ca.* 5.6 ka (Jalut *et al.* 2009) and short-term AP minima (*e.g.* at *ca.* 5.6, 4.7, 4.1 and 2.2 ka) are thought to represent drought events in the Aegean region (Kotthoff *et al.* 2008). Nevertheless, for this later part of the Holocene and due to the advent of the Neolithic period, it is difficult to distinguish climate-induced terrestrial responses from those that should be attributed to the human im-

fact. Since the publication of Vita-Finzi's classic work 'The Mediterranean Valleys', in which he argued for climate forcing behind major last glacial and Holocene alluviation and erosion events (the so-called 'Older' and 'Younger Fill' respectively), a fierce debate has been generated⁴⁶. Geoarchaeological research shifted the 'Vita-Finzi paradigm' towards human agency, manifested in two main ways: settlement expansion accompanied with forest clearance and soil disturbance, and abandonment of land use practices such as terrace maintenance (*e.g.* van Andel *et al.* 1986; 1990a). Although anthropogenic causation is still retained in many interpretations of alluvial aggradation (*e.g.* Lezpez 2003) and not less in pollen-based investigations (*e.g.* Jahns 2005), a better understanding of Holocene climatic variability and the synchronicity of some fluctuations in the Mediterranean (Jalut *et al.* 2009) or globally (Mayewski *et al.* 2004), re-entered climate as a key-player and forced researchers to accept a mutual feedback between climatic triggering and human-induced disturbance (*cf.* Bintliff 2002). Importantly, what seems to progressively gain attention in explaining past landscape changes, is the significance of short-lived, natural extreme events that can be, for instance, related to tectonism (*e.g.* Zangger 1994, for a flash flood at Bronze Age Tiryns possibly associated with an earthquake); or to recurrent but non-linear climatic episodes, bringing torrential rains and/or dramatic reductions in vegetation cover (Thornes cited in Bintliff 2002).

Glacials and stadials

Absolute minima in AP values from the Tenaghi Philippon record show that the most extreme glacial interval of the last 450 kyr was MIS 12 (AP = 0%), followed by MIS 6, MIS 2 and MIS 10, with MIS 8 having the least extreme values, although AP completely disappears during its early part (*ca.* 275 ka; Tzedakis *et al.* 2003b). This pattern generally agrees well with other palaeoclimatic reconstructions (*e.g.* McManus *et al.* 1999) as well as field evidence from Northern Europe, indicating a close link between size

of tree populations and ice volume not only during glacial extremes but also during periods of intermediate ice extent (Tzedakis 2005). However, while during MIS 8d the AP minimum was as extensive as that of MIS 6, this was probably due to suborbital variability (Heinrich-type event) rather than increased ice volume. Extreme phases of open vegetation are not restricted to full glacials, but occur also within interglacial complexes, for instance during MIS 5b and MIS 7d (*ibid.*). For the interval between 920 and 450 ka the TP record shows again a close correspondence with ice volume data, with MIS 22 and MIS 16 displaying the most extreme and sustained AP minima. In fact, MIS 16 emerges as the most extensive glacial of the last 1.35 myr (the base of the TP record), not with regard to AP minima but rather because of the prolonged suppression of tree populations (Tzedakis *et al.* 2006). Interestingly, a marked transition in the vegetational composition of interglacials (thereafter being dominated by *Quercus* and *Carpinus*) occurs after MIS 16, hence at the end of the Mid-Pleistocene Transition and at the onset of the 100-ka periodicity, but it is not clear whether it relates to the effects of the MIS 16 extreme glaciation or to a change in interglacial conditions. Prior to 920 ka, AP minima are comparable to those of the Middle and Late Pleistocene, but their duration is shorter (<10 kyr) than that of MIS 16, 22, 12, 6 and 2 (*ibid.*). Nevertheless, the Early Pleistocene AP minima at TP indicate that even short glacial intervals could occasionally have been severe enough to impose major contractions of tree populations, probably as extreme as in post-920 ka glacials (*ibid.*).

Marine sequences from the Portuguese margin (Roucoux *et al.* 2001), the Alboran Sea (Fletcher and Sánchez-Goni 2008) and the Ionian Sea (Allen *et al.* 1999) document the response of vegetation to suborbital-scale North Atlantic climatic variability during the last glacial, with the largest tree population contractions associated with Heinrich Events (HEs) and less extreme climate changes corresponding to Dansgaard-Oeschger (D-O) stadials. During the low-temperature intervals of the HEs and D-O stadials, this variability would extend eastwards, intensifying cooling and aridity and triggering in-phase responses of terrestrial ecosystems across southern Europe

46. The literature around this discussion is vast and out of the scope of this chapter. For a recent review and references see Bintliff 2002.

(Tzedakis 2004a)⁴⁷. The effects on tree populations would be most dramatic in areas with (a) moderate to low precipitation levels, as southern European forests are largely limited by moisture availability (b) low topographic variability, which reduces protection from polar air incursions, and provides only limited opportunities for altitudinal migrations (Tzedakis *et al.* 2003b). The Ioannina (I-284) pollen core reveals three general vegetation types for the last *ca.* 130 kyr: (1) forest communities during the Last Interglacial, Interstadial I (104.5-88.0 ka), Interstadial II (83-68 ka) and the early Holocene (11.5-5.0 ka); (2) communities of intermediate forest cover during the Middle Pleniglacial (59-26 ka), and Stadials 1 (111.8-104.5 ka) and 2 (88-83 ka) of the last interglacial complex; (3) open vegetation communities with woodland of scattered trees during the Early Pleniglacial (68-59 ka), the Late Pleniglacial (26.0-11.5 ka), and short intervals of the Middle Pleniglacial and during the late Holocene (Tzedakis *et al.* 2002b). The equivalents of the “Oldest Dryas” stadial and the Meiendorf/Bølling/Allerød interstadial complex have been identified in the pollen assemblages of a marine core from the northern borderlands of the Aegean Sea (Kotthoff *et al.* 2008). The Younger Dryas (*ca.* 12.7-11.7 ka) is also identified in the latter record (*ibid*), as well as in terrestrial pollen cores (*e.g.* Tzedakis *et al.* 2002b) and probably in the sedimentary sequence of Theopetra (Karkanas 2001), with all proxies pointing to strongly cold and arid conditions, and contraction/opening of forest cover (see Kotthoff *et al.* 2008 and Karkanas 2001 for references and discussion about the Younger Dryas, which was not, until recently, unequivocally identified in the Eastern Mediterranean).

In Greece, tree growth during the last glacial would have been constrained by increased aridity, lower atmospheric CO₂-content which intensifies water stress, and minimum winter temperatures (Tzedakis

2004a). Comparison of the three main pollen records from Greece shows that those factors had a different impact on tree populations, according to local properties and ecological threshold limits. The Ioannina basin (470 m asl) lies on the west side of the Pindus mountain range and has a sub-Mediterranean climate with high annual precipitation values (~1200 mm). The TP basin is surrounded by mountains and experiences a more continental climate with a mean annual precipitation of *ca.* 600 mm. Finally, Kopais falls within the eu-Mediterranean climatic regime with annual precipitation of 470 mm. In other words, the general trend is one of reduced precipitation from Ioannina to the sites towards the east and south, and of increased temperature from TP towards the south. For the period between 52 to 11 ka BP, pollen diagrams from TP show an almost complete disappearance of trees during HE 4 and 3 and intervening stadials, with low interstadial increases in-between, whilst similar population crashes occur also at Kopais (Tzedakis 2004a). In contrast, the Ioannina record tells a different story: although large reductions do occur, the curves remain continuous for several taxa and the minimum AP values do not fall below 21%, indicating that even during the most severe contractions there was never a complete elimination of tree populations. Palaeoclimatic simulations for the LGM (Pollard and Barron 2003) suggest that the factors controlling precipitation in western Greece today (*i.e.* basically, orographic uplift of air masses bringing moisture from the Ionian Sea) were also at work during the LGM, buffering regional aridity at Ioannina (Tzedakis *et al.* 2004a). According to the simulated values, mean January temperature and annual precipitation were -5°C and ~655 mm at Ioannina, 1°C and 180 mm at Kopais, and -5.3°C and 260 mm at Tenaghi Philippon (Tzedakis *et al.* 2004a). Hence, at Ioannina, precipitation values remained higher than the ~300 mm threshold for tree survival, whereas moisture deficiency at Kopais and TP resulted in extreme aridity and tree population crashes (Tzedakis *et al.* 2002b). Moreover, high topographic variability at Ioannina provided trees with shelter from cold air masses, the opportunity to migrate vertically, as well as a range of microhabitats suitable for survival (Tzedakis 2005). Overall, a rather distinct biogeographical pattern emerges east and west of the Pindus Mountains: the eastern arid and exposed lowlands would experience significant tree po-

47. Related to the HEs of the North Atlantic, polar waters entered the Mediterranean through the Straits of Gibraltar. Cooler sea surface temperatures during these incursions would have inhibited moisture supply to the atmosphere, in turn reducing precipitation on land and enhancing moisture stress in vegetation communities. Rapid climatic oscillations associated with North Atlantic events are also indicated by evidence from the southern Aegean Sea (Geraga *et al.* 2005).

pulation crashes during glacials and stadials, whilst the mid-altitude sites of western Greece acquired a refugial character, providing the sources for survival of residual populations and recolonization during interstadials and interglacials (Tzedakis *et al.* 2002b).

Computational experiments that compare modern conditions with possible climatic scenarios for the LGM at Ioannina reveal increased winter runoff as well as total runoff during the LGM (Fig. 6.5; Leeder *et al.* 1998). As depicted by the monthly soil erosion potential, the distribution of erosion levels is also significantly different between the two periods, reflecting an increase in the seasonality of runoff. Since the modeled values for the LGM indicate annual precipitation similar to that of the present at Ioannina, it is reasonable to assume that the effects of changing water balance upon erosion rates and sediment supply would have been more profound in less humid areas, for example Tenaghi Philippon and Kopais.

Glacial sequences in Greece (and across much of the Mediterranean) were until lately thought to have been generally restricted to the last glacial stage (Woodward *et al.* 2008), and a tentative assignment of glacial units on Olympus Mountain to MIS 8, 6 and 4-2 (Smith *et al.* 1997) could not be confirmed due to the lack of radiometric dates. Recent research on the glacial succession in Greece established a geochronological framework based on a combination of radiometric dating with morpho-lithostratigraphic analyses and pedogenic data. Glacial and periglacial units have been correlated with cold intervals in the pollen stratigraphy of the Ioannina record, which is used as a parastratotype for indirect comparisons with the marine isotope record (Hughes *et al.* 2006c). Altogether, various lines of evidence along with multiple dating techniques allowed the development of a regional chronostratigraphy, which makes the glacial sequence in Greece the best-dated in the Mediterranean and one of the best-dated in Europe⁴⁸. Palaeo-glacial features have been reported earlier for

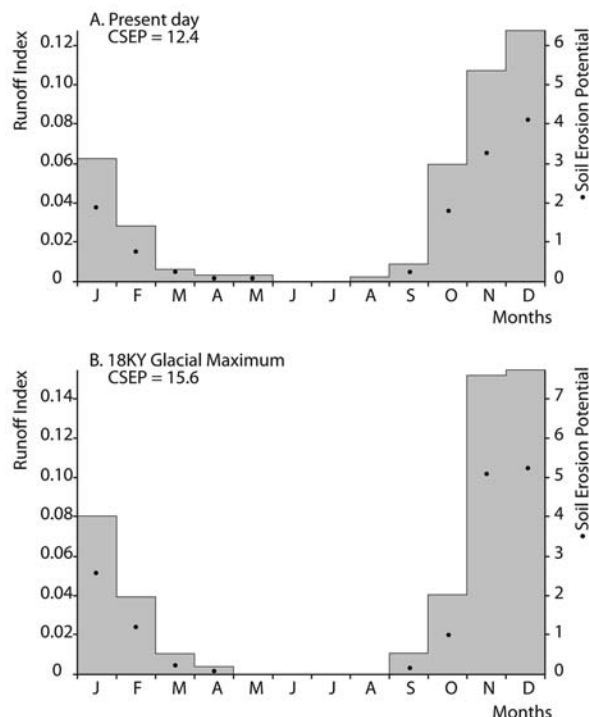


Fig. 6.5 Results of Cumulative Seasonal Erosion Potential (CSEP) experiment, comparing runoff-erosion relationships between present-day (A) and the LGM (B) at Ioannina, north-west Greece (after Leeder *et al.* 1998: fig. 6). The graphs show the values of output once equilibrium has been reached. The CSEP index is essentially a climatic index for soil erosion potential including seasonal and vegetation factors

the mountains of Epirus, Mt. Oeta, Mt. Oxia, the Agraia area and Mt. Parnassus in central Greece, and as far south as Peloponnesus (Mt. Taygetos) and Crete (Woodward *et al.* 1995; Hughes *et al.* 2006b), but the most recent research advances mentioned above refer to Mt. Smolikas and, primarily, Mt. Tymphi; hence the following discussion is restricted to the results from research in the latter two neighboring mountains of the Pindus mountain chain.

The most extensive valley glaciers and ice fields, extending down to altitudes as low as 850 m asl, were formed during the Skamnellian Stage, which is correlated to MIS 12. Vlasian Stage glaciers (MIS 6) occupied mid-valley positions and were not as extensive as the previous ones, but did reach lower elevations than the glaciers of the Tymphan Stage

48. This is stressed here, because, as Hughes and colleagues put it (2006c, 431), "the establishment of a formal stratigraphical framework in conjunction with a nearby reference pollen parasequence has enabled, for the first time, the development of a Middle and Late Pleistocene chronostratigraphy for Greece".

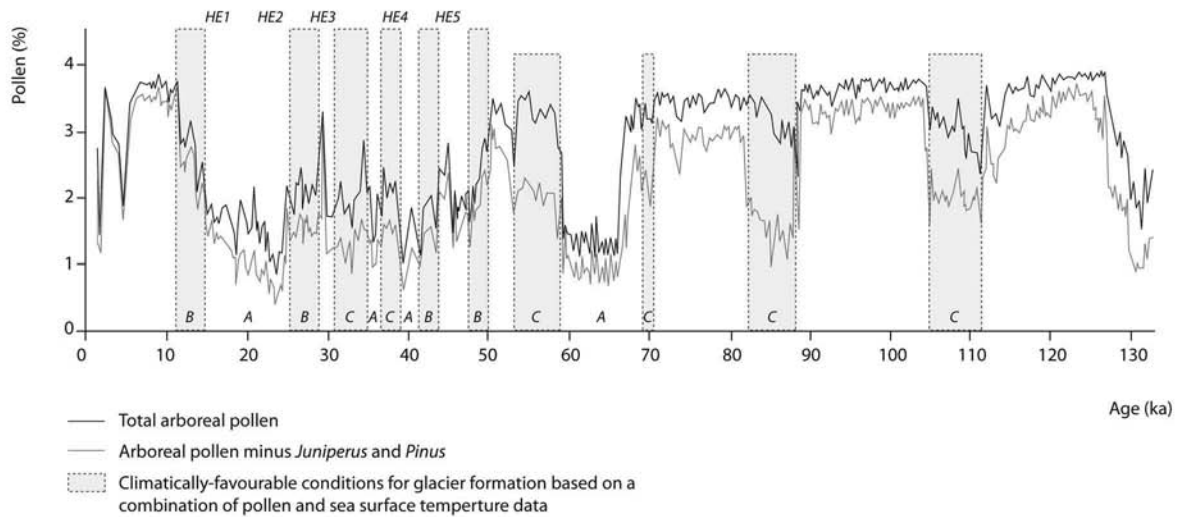


Fig. 6.6 Last glacial pollen curves from Ioannina (I-284) and potential intervals favoring glacial formation. A: major stadials characterized by low arboreal pollen; B: intermediate periods between the peaks of stadials/interstadials; C: intervals characterized by large differences between total arboreal pollen frequencies and arboreal pollen frequencies excluding *Pinus* and *Juniperus*. Heinrich events (HE) are also shown. Modified after Hughes *et al.* 2006a: fig. 5

(MIS 5d-2) (Hughes *et al.* 2007b). A similar pattern in the amplitude of glaciations, going in decreasing order from MIS 12 to MIS 6 and then 2, is reflected in the Ioannina pollen record; additionally, Late Pleistocene glaciers appear to have been significantly smaller than those of the Middle Pleistocene also in NW Spain, the Pyrenees and the Apennines (Hughes and Woodward 2008).

Hughes and colleagues (2006a) argue that the forming and decaying of Mediterranean mountain glaciers would have been fluctuating in response to the millennial-scale climate oscillations of the last glacial, and, by using the Ioannina record as a reference, they have identified at least ten time-windows that would have favored glacial formation (intervals labeled 'B' and 'C' in Fig. 6.6). Suitable conditions for glacier formation would not have been met during the climate extremes of stadials (including HEs) and interstadials, but rather during intermediate phases, when the climate was sufficiently wet -but not too warm, as during interstadials, and sufficiently cold -but not too dry, as during stadials. The last such glacier-favorable phase before the most severe and driest peak of the last glacial, occurred between 30,000-25,000 cal years BP, which is also the time of deposition of a major alluvial unit in the Voidoma-

tis basin (Woodward *et al.* 2008). In short, glaciers on Pindus are likely to have decayed during stadials and interstadials and advance during intermediate conditions of 'cold-yet-moist' climates, rather than during the regional peaks of extreme climate (*i.e.* at *ca.* 24,000 cal. years BP in Ioannina record) or the global LGM (21,000 cal. years BP; *ibid.*). Instead, during the heights of climatic extremity and a shifting to drier regimes, periglacial phenomena, such as rock glaciers and debris accumulation would have been prevalent (Hughes *et al.* 2003). Glacier behavior would have been unstable and glaciers may have been responsive to centennial- or even decadal-scale changes, given their small size (Hughes *et al.* 2006a).

Insights into the climatic conditions of the Middle Pleistocene glacier maxima on Mt. Tymphi can be extrapolated relative to the above-mentioned glacier-climate reconstructions. Thus, the lower equilibrium line altitudes of the Vlasian Stage (MIS 6), compared to those of the Tymphian, can be attributed to lower summer temperatures and/or higher precipitation (Hughes *et al.* 2007). Indeed, other records indicate that MIS 6 was as cold as the last glacial but with higher precipitation, as it is documented for instance between 180-170 ka (*ibid.*, 55). By extension, Skam-

nellian (MIS 12) glaciers would have formed under even lower temperatures and/or higher precipitation than their successor, since they were the most extensive ones. In fact, during the Skamnelliian Stage, climate can be envisaged as even colder and/or wetter than that of both the Vlasian and the Tymphian stages, with summer temperatures *ca.* 11.1°C lower than present, representing the coldest mean summer temperatures recorded in Greece for at least the last 430,000 years (Hughes *et al.* 2007). At lower altitudes such as that of nearby Ioannina (484 m asl) mean summer temperatures would have been $\leq 12.4^{\circ}\text{C}$, with winter temperatures at least -0.8°C and perhaps significantly less than that. Overall, continental conditions would have accentuated periglacial processes and physical weathering, promoting frost shattering of bedrock over large areas of the Pindus Mountains and hence also increasing the sediment supply in river systems. Importantly, between these extremely cold highlands and the very dry lowlands, the intermediate climatic zones would have been significantly narrowed compared with later glacial phases (*ibid.*).

The Voidomatis river basin, with its highest reaches and headwaters lying within the glaciated areas of Mt. Tymphi, offers now a well-dated record of glacio-fluvial activity, representing the long-term response of the fluvial system to changes in sediment supply and valley-floor geomorphology driven by changes in the location and volume of glaciers (Woodward *et al.* 1995; 2008). The influence of glaciations to alluvial channels, by, for instance, enhanced flood magnitude and sediment supply, extended to low elevations below 500 m asl. and even to the coastal zone. Meltwater and sediment fluxes were probably greater in both magnitude and amplitude during the Skamnelliian Stage, indicating a *strong coupling* between the upland glaciated plateaus and the middle and lower reaches of the Voidomatis. However, fluvial sediments of pre-MIS 6 glaciations have been either not preserved or buried below ‘Vlasian’ deposits. The latter are represented in one alluvial unit that indicates a major increase in sediment supply from the upstream catchment; remarkably, such major aggradation episodes, correlated to MIS 6, have been identified elsewhere in the Mediterranean as well (Macklin *et al.* 2002). Nonetheless, as in the case of MIS 12, Vlasian deposits

are not well-preserved, and this is explained by the geomorphological setting: in high energy, narrow and incised gorges, long-term storage of sediments is not favored, because the formation of new valley-floor units proceeds at the expense of reworking earlier ones. This is evident in the Voidomatis record, where Late Pleistocene units are seen as the result of large floods that reworked glacial material, which had been deposited during the Middle Pleistocene glaciations. In turn, this partly explains that, although the Tymphian glaciers were the smallest ones, large-scale aggradations took place downstream by reworking limestone-dominated and till-derived coarse sediments that were inherited from previous glaciations. Woodward and colleagues (2008, 55) note that “the pattern of coarse sediment reworking and downstream transfer observed in the Late Pleistocene alluvial record [...] may be a good model for the earlier glacial-fluvial interactions of Stage 12 [...] In other words, the Middle Pleistocene glaciations may have generated extended periods of paraglacial sedimentation”. Strikingly, large amounts of limestone in the Holocene and modern river gravels may be reflecting the *continued reworking* of coarse-grained material that belongs to the legacy of former, Middle Pleistocene glaciations (*ibid.*).

6.2.4 Geomorphic responses to Quaternary climate changes, fluvial erosion and slope processes

Apart from the example of the Voidomatis river responding to glaciations on the Pindus Mountains, the sensitivity of Greek and other Mediterranean rivers to Quaternary climate changes is now sufficiently understood for at least the last 200 kyr, for which a relatively reliable dating control has been acquired (Macklin *et al.* 2002). Either referring to terraced fluvial sequences (*e.g.* Lewin *et al.* 1991; Woodward *et al.* 1995) or to alluvial fans (*e.g.* Demitrack 1986; Wilkinson and Pope 2003), there is a widely held consensus in correlating episodes of alluvial sedimentation with glacial/stadial periods and intervals of non-deposition/stability and/or incision with interglacial/interstadial periods (Macklin *et al.* 1995). Soil formation is also usually attributed to milder climatic conditions and soils mark the position of buried or relict palaeo-surfaces, overall representing periods of relative geomorphological stability (Woodward *et al.* 1994).

Although such one-to-one correlations (*i.e.* glacials-aggradation, interglacials-incision) have been recently challenged (for a review see Vandenberghe 2003) and great caution is needed before a direct link is demonstrated (*e.g.* Pope and van Andel 1984), results from latest fluvial research in Greece and the Mediterranean seems to corroborate this notion (Macklin *et al.* 1995; 2002; Woodward *et al.* 2008), notwithstanding the decisive role of local intra-basin attributes (*e.g.* topography, lithology; Wilkinson and Pope 2003), tectonic controls (*e.g.* Starkel 2003) or preservation biases (Bridgland and Westaway 2008a). At a 100 kyr-scale (*i.e.* a glacial-interglacial cycle), fluvial responses are broadly climate-dependent within the regional tectonic frameworks; at the 104-timescale, responses are conditioned mostly by indirect climatic impacts (*e.g.* vegetation-soil-runoff relationships), whilst at the 1000-yr and 100-yr timescales, intrinsic properties of the hydrological system and threshold conditions (*sensu* Schumm 1979), either climatic or terrestrial, become most striking (Vandenberghe 1995)⁴⁹. At the largest scales (10^5 and 10^4) unstable phases coincide with the major climatic transitions (glacial-to-interglacial and *vice versa*) and this would be also true for 10^2 - and 10^3 -scales and the sub-MIS transitions (*e.g.* at the MIS 5b-5a boundary; Macklin *et al.* 2002). The problem with the latter transitions (of higher-frequency, lower-amplitude events within a glacial or interglacial stage) is that they are reflected by short-lived and sporadic episodes in the fluvial archive, which are usually either not preserved or impossible to grasp by the available geochronological techniques, as the confidence intervals on the dates typically overlap. Therefore, considering that short unstable phases alternate with longer periods of inactivity (and/or stability), the critical question remains: how short are these unstable phases and their recurrence intervals? Hosfield and Chambers (2005, 291) argue that, for north-west European fluvial systems, the time-spans of fluvial incision/erosion and

sedimentation stretch over a few hundreds or at most a few thousands of years; and that archaeological assemblages in fluvial sedimentary contexts are “*unlikely* to have lain undisturbed on river floodplains and/or channel margins for more than 2-3 kyr between major/minor episodes of fluvial activity”. The latter authors suggest that artefact accumulations which are now associated with secondary fluvial contexts, would be reworked into fluvial sediments *every few thousand years*; hence they represent temporal palimpsests with a time-depth that varies according to site-specific factors but is generally in the order of a few thousand rather than tens of thousands of years (*ibid.*, 294). Although this conclusion was drawn based on north-west European fluvial research, it can be viewed as broadly applicable to Mediterranean landscapes, for reasons that I explain below.

By both global and Mediterranean standards, most of the river basins in Greece are small, and, taking the 500 m contour as the mountain-lowland boundary, are drained by steep-land river systems⁵⁰. This configuration stems from an intense (and still active) tectonic history that sets the background for a basin-and-range topography, which has restricted the development of extended alluvial channel reaches (Macklin *et al.* 1995, 19). Coupled with a strong climatic seasonality, this results in hydrological regimes that are marked by steep hydrographs⁵¹ (Paspallis 2003). Moreover, sediment yield data from Mediterranean landforms lie high above the world averages, and rates of erosion are one or two orders of magnitude higher in basins with steep relief (Inbar 1992).

Besides rivers that are fed by groundwater in limestone terrains, Mediterranean river regimes today reflect the seasonality in the distribution of precipitation, and runoff patterns essentially result from rainfall alone (Macklin *et al.* 1995, 12). In most of Greece, rainfalls occur during winter or winter and autumn, with small parts of the NE and the NW ex-

49. Although these scale-related relationships stem from research in north-west Europe, they have been noted by researchers working in Greece as early as in the 1980's (*e.g.* Pope and van Andel 1984), and are reflected also in more recent publications (*e.g.* Wilkinson and Pope 2003), even if the authors do not touch these issues explicitly or as a primary focus.

50. Overall, there exist an inverse relationship between slope steepness and the extent of drainage area; see for example the plot of valley slope/drainage area in Schumm 1979.

51. A hydrograph plots the discharge of a river as a function of time.

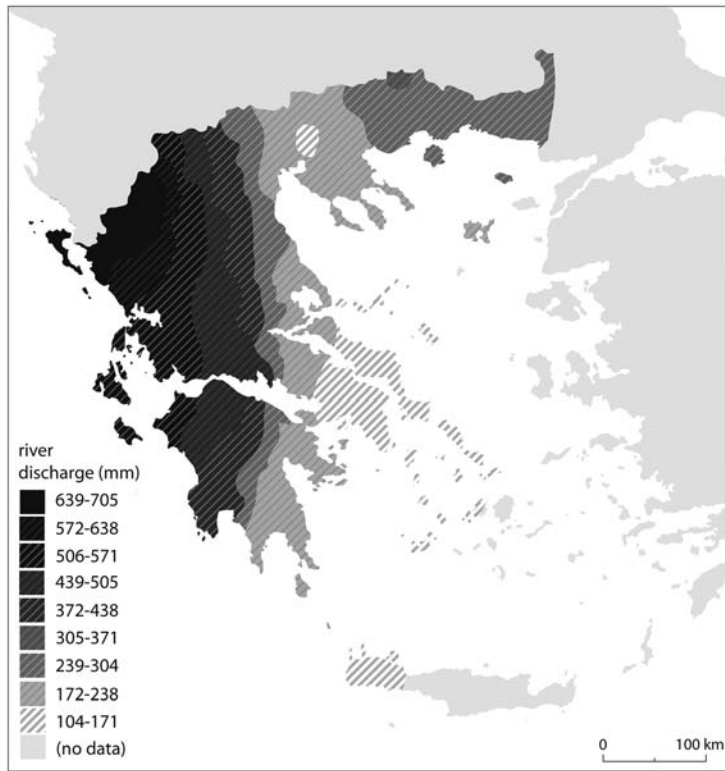


Fig. 6.7 Total annual river discharge in Greece. A comparison with Fig. 6.1 shows clearly how runoff patterns follow closely those of rainfall. Source: (Greek) National Data Bank of Hydrological and Meteorological Information

periencing rainfall peaks during autumn, whilst only the north-central part has rain throughout the year (Bartzokas *et al.* 2003). In other words, because of the seasonality in the distribution of precipitation, fluvial runoff in most of Greece is also seasonal (Mimikou 2005), chiefly concentrated in a few months of the year, with a winter or early spring peak and minimum flow in the summer (Fig. 6.7).

As noted earlier, similar spatial climatic patterns characterized the last interglacial, and, indeed, we can envisage a comparable situation for other past interglacials (Tzedakis 2000; Cheddadi *et al.* 2005), expecting perhaps a further increase in seasonality for those interglacials that were warmer than today, resulting in an accentuation of the summer (drought) season. On the other hand, during cold stages, river regimes were most probably even more seasonal and displayed greater spatial and temporal variability (Macklin *et al.* 1995). Notwithstanding this variability, seasonal flow fluctuations in rain-fed catchments would have been more pronounced, especially in southern and eastern areas, but also in northern sites with a more continental climatic regime (*e.g.* TP). Increased seasonality of precipitation has already been

suggested for the LGM (Prentice *et al.* 1992), whilst excess precipitation may have taken the form of extreme storm events during the early parts of interglacials, and this latter situation could be reflected in the absence of alluvial units dated to the early part of the last interglacial, which emerges as a period of valley floor incision with soil development on stable terrace surfaces (Macklin *et al.* 2002, 1638). Given that, as stressed with regard to documented events (*e.g.* Kosmas *et al.* 1997; 2000), the dominant driver of erosion is the precipitation input, any increase in the ephemerality of flow regimes and/or a decrease in the recurrence interval of high-discharge peaks that interrupt periods of quiescence, would result in river regimes with even steeper saw-tooth hydrographs, perhaps along with concomitant increases in the frequency of high-magnitude, short-lived extreme flood events; and these are, ultimately, the major causes of landscape disturbances and soil erosion. Results from recent physically-based modeling of the effects of seasonality on annual and intra-annual water balance support the arguments above (Yokoo *et al.* 2008): the presence of climatic seasonality tends to decrease evapotranspiration and increase runoff compared to when there is no seasonality; and the effects of sea-

sonality are stronger when seasonal variability of precipitation and potential evapotranspiration are out of phase; moreover, this tendency increases as the dryness index increases (*e.g.* in semi-arid areas), and seasonality effects are high in basins with steep topographies.

Due to the small size of the Mediterranean drainage basins and the fact that most of them include high-relief, steepland catchments, there is an overall strong slope-channel coupling, in contrast to lowland rivers of north-west Europe, which are thought to have a less effective coupling between hillslopes and stream channels (Macklin *et al.* 2002). In effect, processes operating in upland reaches are quickly affecting lower areas downstream, and we have already seen that changes in sediment supply in the uplands (*i.e.* >2000 m asl) of the Voidomatis river extended their influence below 500 m asl and down to the coastal zone. As Grove and Rackham vividly put it when describing river erosion after a deluge in Crete (2001, 248), “although rainfall was presumably more than 300 mm in the mountains, the greatest effects were at low altitudes...Most of the mayhem in the valleys was the recycling of deposits already in them”. Reworking of older sediments by renewed aggradation and erosion has already been noted for the Voidomatis river, where it was stressed that there is evidence for the post-glacial, Holocene river still reworking glacial (till-derived) material. Furthermore, the slope-channel coupling would have been even more accentuated during, for instance, extreme glacial stages (*e.g.* MIS 12), when transitional climatic zones between uplands and lowlands were narrowed.

According to the above, if episodes of incision/erosion and alluviation in NW Europe “occur across timespans stretching over a few hundred, or at most a few thousand years” (Hosfield and Chambers 2005, 291), it could be argued that this may be very well true also for Greek catchments during both interglacial and glacial stages. In fact, it could be equally possible that river systems in Greece experienced even more “rapid chronologies” (*ibid*) and fluvial events had an even shorter duration and/or recurrence intervals, with process-response patterns orchestrated by climatic oscillations and accommodated in the highly dynamic background of a steep

relief and omnipresent tectonism. Even if we neglect the undoubtedly critical role of topography and tectonics, the assertion above would be perhaps falsified only if suborbital, rapid climatic oscillations either did not occur or did not affect Greece, and/or if the coupled slope-channel system in watersheds did not respond equally fast. But that is most likely not the case. As attested by the Greek pollen records, centennial-millennial climatic fluctuations did occur and influence Greek landscapes, triggering in-phase responses of terrestrial ecosystems (Tzedakis *et al.* 2004a; see above). In Italy, the Monticchio pollen sequence furnished varved-counted intervals of decades-centuries for the end of the last interglacial (Brauer *et al.* 2007), whereas, for Greece, the last glacial glaciers of Tymphi are assumed to have been responsive to centennial- or even decadal-scale changes, given their small size (Hughes *et al.* 2006a, 95). Thus far, the available chronological control for Greek and other Mediterranean fluvial archives does not permit a precise estimation of the length of time over which depositional and/or erosional events occurred, but there have already been suggestions for catchment-wide sedimentation “over time periods of between 10^3 and 10^4 years” (Macklin *et al.* 2002, 1640), hence supporting the arguments presented here. Examples from the Holocene cannot be extrapolated to past climatic cycles because of anthropogenic interference, but are still elucidating how brief depositional events can be (at least from the Neolithic onwards): a late Holocene alluvial episode in Southern Argolid lasted less than 2-3 centuries, whereas 5 m of Holocene alluvial sediments in the Argive plain accumulated in a maximum of 50 years (van Andel and Zangger 1990).

However, is it then possible to see these ‘rapid chronologies’ as a general trend for all Greek basins? Harvey (2002, 198) notes that “in well-coupled systems, assuming effective thresholds are exceeded, and especially where there is a rapid response to environmental change, there is likely to be near synchronicity and spatial uniformity in the geomorphic response to environmental change. In well-coupled systems, the results of such changes will be basin-wide aggradation or dissection sequences.” On the other hand, Pope and van Andel (1984) and Wilkinson and Pope (2003) showed that aggradation and dissection were much more localized and varied throughout the ba-

sins of Argolid and Evrotas River, respectively, and this would indicate a rather poor coupling with depositional/erosional records representing only local sequences. Still, “in poorly coupled systems, there is likely to be spatial non-uniformity, and possibly major contrasts in process regimes or stability between different parts of the system, but nevertheless, those parts of the system affected by environmental change would respond fairly rapidly” (Harvey 2002, 198). Consequently, the argumentation on the relative duration of events and/or the frequency of recurrence is not critically affected whether the basin systems are well-coupled or not, and notwithstanding the wide range of variability in inter- and intra-basin processes.

6.2.5 Discussion

Dating and preservation constraints (*e.g.* hiatuses) restrict the actual basis of the above-listed documented patterns and extrapolated assumptions to events of the Late Glacial and early Holocene. Therefore, the question is whether they are applicable to earlier periods. Early and Middle Pleistocene suborbital climatic oscillations are not as well-known as Late Pleistocene ones, but they do emerge in high-resolution records, as it is the case for MIS 7 in the latest core from Ioannina (Roucoux *et al.* 2008) or for MIS 8, in which the vegetation contraction during substage 8d is thought to be related to a Heinrich-type event (Tzedakis 2005). Furthermore, such ‘sub-Milankovitch’ fluctuations have been recognized for the interval of *ca.* 0.5–0.34 Ma (Oppo *et al.* 1998) and even for 1.0–0.7 Ma, displaying highest amplitudes during interglacials, particularly after *ca.* 900 ka: short oscillations occur during the transitions of MIS 25–24, 23–22 and 19–18 (Head and Gibbard 2005, 5). Already in 1993, the Greenland Ice-Core Project members reported on the intra-MIS 5e oscillations, noting that “the mode switches may be completed in as little as 1–2 decades and can become latched for anything between 70 yr and 5 kyr” (GRIP members 1993, 207). On the basis of ice-core data, there are now suggestions that glacial-to-interglacial reversals in the MIS-scale “may have been equally as rapid” (McNabb 2005, 290). In short, if we accept that climatic oscillations in both the MIS and sub-MIS scales are linked with fluvial activity in the order of 10^2 - and 10^3 -phases, then similar associations are

likely to be valid for the Middle and even the Early Pleistocene. The fact that they are hardly detectable is most probably an artefact of the low-resolution in dating methods, the incomplete representation of climatic events in terrestrial archives and the fragmented preservation of these archives (*cf.* Hosfield and Chambers 2005, 293).

Different lines of evidence, from pollen diagrams (*e.g.* Tzedakis 2005), glacial records (*e.g.* Hughes *et al.* 2006c), glacio-fluvial sequences (Woodward *et al.* 2008), lacustrine stratigraphies (*e.g.* Okuda *et al.* 2001), pedogenic data (*e.g.* Woodward *et al.* 1994), alluvial sequences (*e.g.* Wilkinson and Pope 2003) and cave records (Karkanas 2001), all point to the conclusion that landscape instability was prevailing during climatic transitions. In Theopetra Cave, cryogenic events that record climatic deteriorations have been correlated with Heinrich Events of the Late Glacial and have been shown to be followed by major erosional episodes, alternating with periods of milder conditions and stability (Karkanas 2001). The evidence from Theopetra suggests that erosional events may be more prominent during changes from cold to warmer conditions (*ibid.*, 392), which has also been assumed for the fluvial sequence of Pineios in the same region (Demitrack 1986). This may be related to the picture from the pollen record, which documents abrupt oscillations during the climatic shifts from MIS 8 to 7e and MIS 6 to 5e, indicating that such short-lived spells may have been a consistent attribute of cold-to-warm transitions (Roucoux *et al.* 2008, 1392).

A few years ago, the recognition of sub-orbital climatic variability within the last glacial revolutionized our view of Quaternary climates. At present, there is evidence that such rapid switches (Fig. 6.8) were not confined to the last glacial but occurred also during earlier glacials and interglacials, as well as during transitional phases. Both the rate and the amplitude of those sharp reversals would have had major implications with regard to terrestrial responses. Climatic seasonality, precipitation, and the seasonality of precipitation, have been stressed here as crucial factors in this context. Fluctuations in any of these variables would have imposed major stresses in landscape stability, with significant consequences for the preserva-

tion, visibility and reworking of archaeological assemblages.

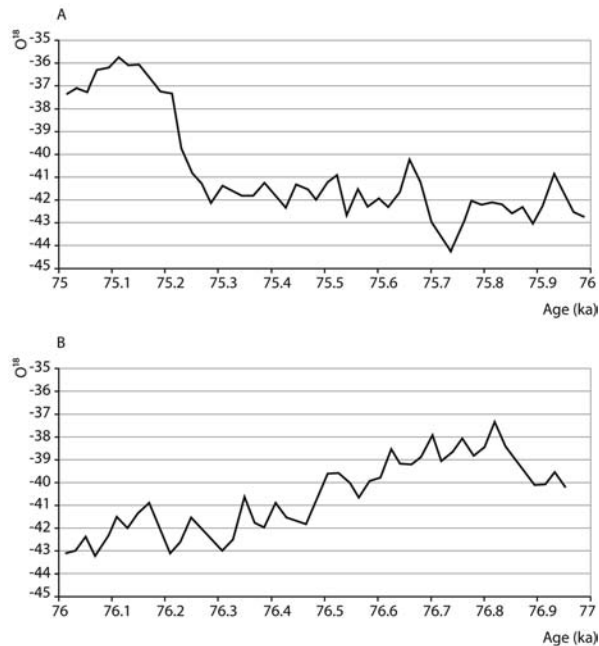


Fig. 6.8 Centennial and sub-centennial climatic changes during 76–75 ka (A) and 77–76 ka (B), as revealed in the GRIP ice-core. After McNabb 2005: fig. 1

We can therefore assume that the most stable geomorphological conditions would be confined to full glacial (stadial) and full interglacial (interstadial) periods. Yet, this proposition is valid in the most relative terms and runs the risk of lumping together periods of geomorphic activity with phases of inactivity, due to the complexity of process-response patterns and our inability to accurately pinpoint the respected intervals. For instance, paraglacial processes –*e.g.* in the form of slope failure, debris flow or fluvial reworking of sediments– are at work when deglaciated landscapes readjust to nonglacial conditions (Ballantyne 2001). On the Pindus mountains, when recently deglaciated terrains would have been in an unstable or metastable state with accelerated erosion prevailing in the context of deglaciation, paraglacial environments would be promoted under full (rather than intermediate) stadial and interstadial conditions (Hughes *et al.* 2003). Conversely, instability associated with ice progression phases, when erosion rates are increased along with glacial advances,

would correspond to ‘intermediate periods’, *i.e.* those in-between the regional peaks of extreme climate. This example is used here to stress that, according to regional spatio-temporal circumstances, climatically-induced instability would not have been restricted only to transitional phases: rather, it would occur also within the relatively ‘stable’ climatic conditions of a full glacial and full interglacial period. In this light, suborbital events within interglacials (*e.g.* MIS 9e, 7e and 5e) were also highlighted here, as they mark the end –and possibly also determine the duration– of interglacial climatic optima (Desprat *et al.* 2009).

6.3 TECTONIC CONTROLS

6.3.1 Introduction

Whereas patterns of erosion and deposition (*e.g.* fluvial incision and aggradation) are largely climatically induced, these patterns are superimposed on tectonic movements, which in turn provide the underlying mechanisms for the development of topography (*e.g.* Cloetingh *et al.* 2007). In other words, if climate can be considered as the main agent of external forcing upon landscape configuration, tectonism constitutes the internal forcing of geomorphological evolution (Bloom 2002). Tracing this kind of tectonic controls over the landscape and the associated Lower Palaeolithic record that we find today, this chapter addresses two main issues:

1. The kind of tectonic regime that was prevalent during the Pleistocene, its origins and the heritage that it left upon the present landscape.
2. How did this tectonic regime influence and control large-scale geomorphological processes, particularly with regard to the preservation and visibility of the (Pleistocene) geoarchaeological record.

Despite Greece being in a convergent plate-tectonic setting, with the African plate subducting below Europe, during the Alpine orogeny (*i.e.* from the Cretaceous up to Miocene), the Internal Hellenides and the Rhodope experienced widespread extensional tectonics, notably since the Oligo-Miocene (Gautier *et al.* 1999). Here we focus in the extension that affected Greece from the Miocene onwards. The present configuration of the Greek landscape is es-

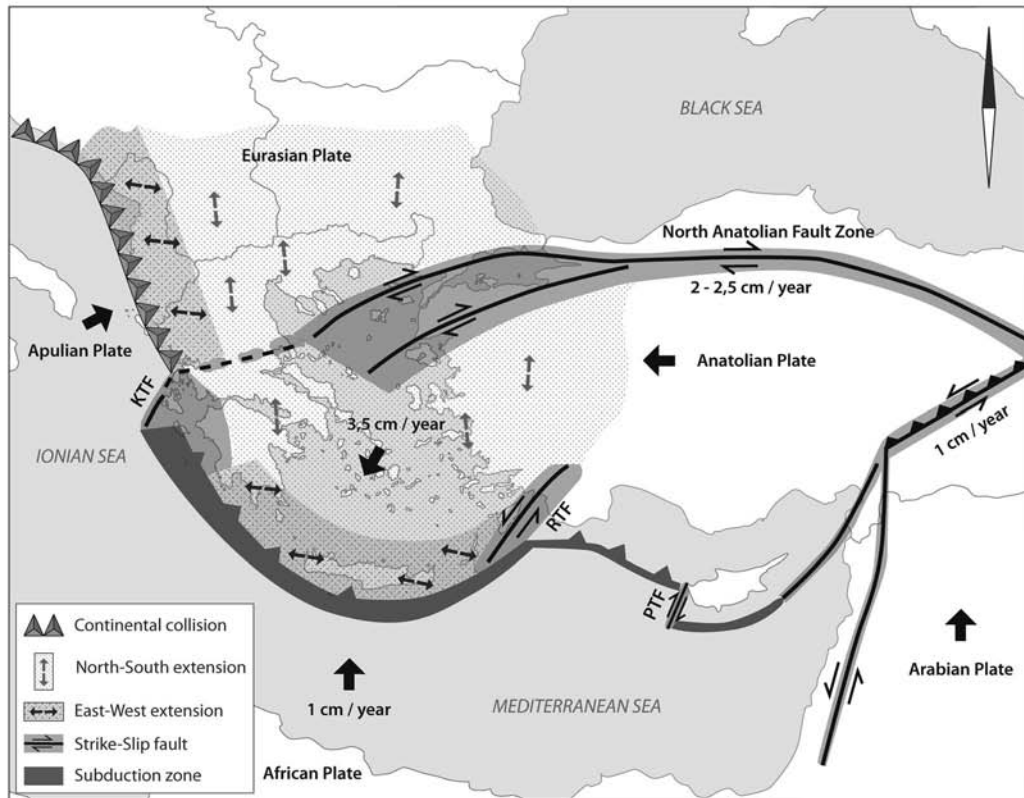


Fig. 6.9 Map of the eastern Mediterranean showing the presently active geodynamic domain in the broader Aegean area. KTF = Kephallonia Transform Fault, which marks the area where the zone of subduction gives way to a zone of continental collision between the Apulian and the Eurasian plate. Modified after Mountrakis, university notes (<http://www.geo.auth.gr/courses/ggg/ggg871y/>)

essentially the result of late-orogenic tectonic movements that affected the Hellenic Peninsula since the Miocene and largely continue until today (Meulenkamp 1985; van Hinsbergen *et al.* 2006). These movements were polyphase and complicated, including both extensional and compressional events, within tectonic regimes that were often fundamentally opposite in adjoining areas and with multidirectional and highly variable axes of stress and deformation (Angelier 1978). Therefore, important aspects of the kinematic evolution of the region, such as the timing and style of deformation or the temporal and spatial distribution of strain, still remain controversial (Aksu *et al.* 2005).

6.3.2 Overview of the main tectonic phases

The Aegean region is one of the most rapidly deforming regions in the world (Jackson 1994; Cloe-

tingh *et al.* 2007) and seismically the most active region in the Mediterranean and West Eurasia (e.g. Tsapanos *et al.* 2004). The Aegean Sea is an extensional back-arc basin that formed as a result of differential convergence rates associated with the north-eastward subduction of the African plate beneath the Eurasian plate (Mather 2009). Intense and widely distributed extension commenced in the Miocene (Le Pichon and Angelier 1979), with time it migrated south-westward and was accommodated along a series of large-scale normal faults on the Hellenic Peninsula (Angelier 1978), and at present it remains ongoing (e.g. Billiris *et al.* 1991; Reilinger *et al.* 2010). This extensional regime is genetically related to two first-order structures (Doutsos and Kokkalas 2001; Fig. 6.9): the North Anatolian Fault Zone (NAFZ, including the North Aegean Trough) and the Hellenic subduction zone (or, 'Hellenic Trench'). The NAFZ was activated during middle to late Miocene times

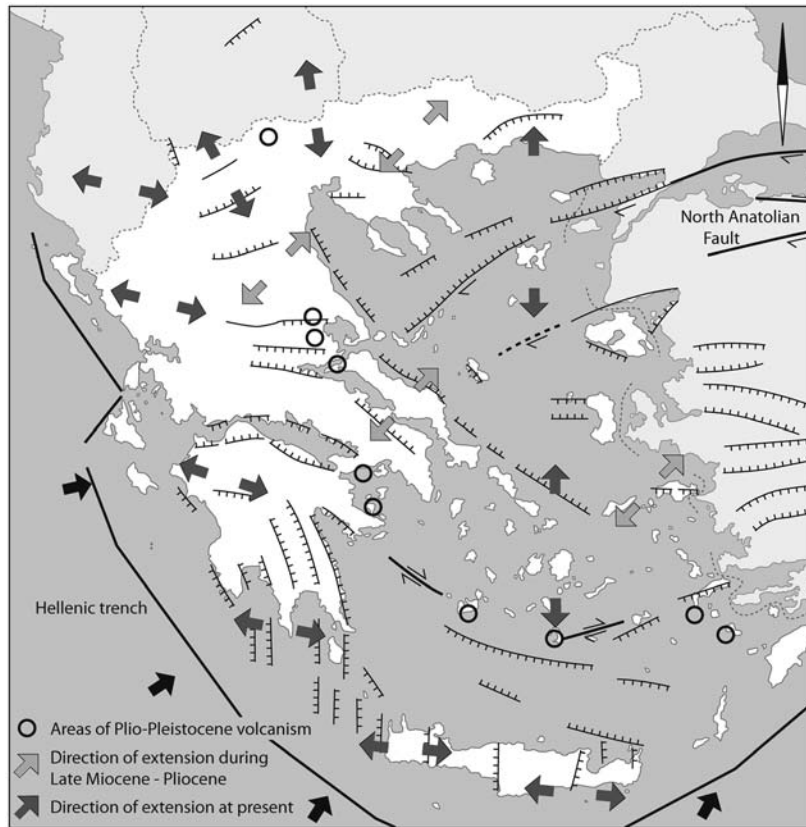


Fig. 6.10 Extensional tectonism and major faults in the Aegean region. Black arrows show the movement of the African plate and the direction of compression in the Ionian Sea. Modified after Mountrakis, university notes

and facilitates westward escape of the Anatolian block, which is driven in response to the northward collision of the Arabian plate into the Eurasian plate (Sengör *et al.* 2005). The Hellenic arc defines the southern boundary of the Aegean extensional domain, along which the African plate is consumed northwards; in most geodynamic models this subduction zone represents the ‘free edge’ allowing the Aegean lithosphere to either spread or translate the push of the Anatolian microplate (Gautier *et al.* 1999). The onset, spatio-temporal evolution and driving mechanisms of the extensional regime are related to these two structures (NAFZ and Hellenic Trench), with some authors emphasizing the role of the westward push of the Anatolian microplate (*e.g.* Jackson 1994), whereas others underline the subduction roll-back and trench suction along the Hellenic arc (*e.g.* Le Pichon and Angelier 1979), which constituted the outer boundary of the Aegean spreading sheet probably already from the early (Gautier *et al.* 1999) or middle-late Miocene (Le Pichon and Angelier 1979).

Tensional subsidence of the Thrace basin started during the late Eocene and the oldest extensional basins of the Hellenides were formed in the Rhodope (Burchfiel *et al.* 2003). Early Miocene N-S to NNE-SSW extension shaped the Katerini Basin north of Mt. Olympus and the Klematia-Paramithia half-graben in Epirus (van Hinsbergen 2004). Subsequently, the extensional regime invaded the central and southern Aegean, reaching the latter by the late Miocene (around 11 Ma); by that time, E-W extension and increased subduction affected the south Aegean area, whereas between 15 and 8 Ma compressional deformation during 40° clockwise rotation shaped the western Aegean domain (van Hinsbergen *et al.* 2005; Cloetingh *et al.* 2007). Late Miocene extensional stresses resulted also in the formation of the basins of the North Aegean region, namely those in the areas of Kavala, Xanthi, Komotini and Alexandroupolis (Rondoyanni *et al.* 2004), as well as those associated with the Strymon River (Snel *et al.* 2006; see also below, Fig. 6.11). During late Miocene to Pliocene (*ca.* 8-3.5 Ma), E-W extension accelerated in southern Greece and the entire Aegean-West Ana-

tolian domain experienced a new extensional phase that overprinted the earlier-formed grabens (*ibid*; van Hinsbergen 2004). Northeast-southwest extension (Fig. 6.10) created the lacustrine Florina-Vegoritiss-Ptolemais basin system in Macedonia (Pavlidis and Mountrakis 1987) and the intramontane Larissa and Karditsa basins in Thessaly (Caputo *et al.* 1994), whereas a stress field of the same direction impacted also on the basins of eastern Macedonia and Thrace (Rondoyanni *et al.* 2004). Compressional movements affected the Ionian Islands, and the entire western coast of Greece was subjected to strong uplift (Doutsos *et al.* 1987; van Hinsbergen *et al.* 2006). This compressional regime, with folding and thrusting on the Ionian Islands and the western parts of the mainland, results from the convergence between the underthrusting Apulian plate and the Aegean plate, and it led to the formation of taphrogenic basins trending parallel and transverse to the already existing Alpine folds (*ibid*).

The last phases of landscape development took place from the late Pliocene up to the present, when southwestward motion of Greece continued and most of the seismically active structures that we see today were formed (Jackson *et al.* 1982; van Hinsbergen 2004). Specifically, most of the systems of horsts and grabens that at present divide the modern topography into rising and subsiding blocks were generated during this period, and are best exemplified in central Greece, which displays the classic basin-and-range type of extensional area (Angelier 1978). With internal deformation increasing, the basins were subjected to the strong influence of a N-S extension, whilst the impact of an E-W extensional trend was being superimposed, escalating gradually from north (west) to south(east) (van Hinsbergen *et al.* 2006). This is indicated by the curved form of the main basin systems in central Greece and Peloponnesus, namely that of the Gulf of Patras-Gulf of Corinth-Saronic Gulf, the Ambracian Gulf-Spercheios Basin-Gulf of Euboea, as well as the Pyrgos Basin-Megalopolis Basin-Evrotas Basin system, all of which are marked by N-S extension in the northwest, grading into E-W extension in the southeast (*ibid*). Recent studies showed that around 2.2 Ma a major change in internal plate dynamics resulted in the majority of active strain within the Aegean-Anatolian

plate becoming focused along the Corinth margin (Leeder *et al.* 2008).

During the early Pleistocene, compression was affecting the western marginal parts of the Aegean micro-plate, with the most profound compressive structures occurring in the Ionian Islands (Angelier 1978). This outer compressive regime invaded the Aegean during the early-middle Pleistocene, but the prevailing tectonics were still mostly extensional, although reverse faulting persisted and still continues in the Ionian Sea (*ibid*). Compressional episodes of smaller amplitude than those prevailing in western Greece and the Hellenic Trench are thought to have interrupted longer periods of extensional tectonics in the central and northern Aegean. However, some authors have argued that these apparently compressional episodes are probably not regional in extent and may not be truly compressional in origin (*e.g.* Jackson *et al.* 1982).

Quaternary palaeogeographic and temporal reconstructions of vertical movements – and particularly the explanation of uplift during extensional conditions⁵² – are still debatable (*e.g.* Angelier *et al.* 1982; Moretti *et al.* 2003; Westaway 2007), but during the Plio-Pleistocene/Early Pleistocene a regression probably resulted in the formation of (semi)adjoining landmasses in the Aegean (Mountrakis 1985). During the Middle Pleistocene and while compression continued in western Greece, extensional movements caused widespread depressions which in turn resulted in periodic and eustatic-related transgressions (*ibid*; Lykousis 2009; see also section 6.4). Although the prevailing tectonic regime remained extensional in the entire course of the Quaternary and up to the present, the early-middle Pleistocene seems to mark local and/or regional changes with regard to tectonic movements, according to various lines of evidence from different parts of Greece. A change in the direction of stretching affects Thessaly, with important implications for the hydrographic balance and the (re) location of the main depocenters (Caputo and Pav-

52. For example, the explanation of differential uplift along the southern coast of the Gulf of Corinth (see below) is still controversial and many authors believe that the cause may be external to the extensional system itself (Rohais *et al.* 2007).

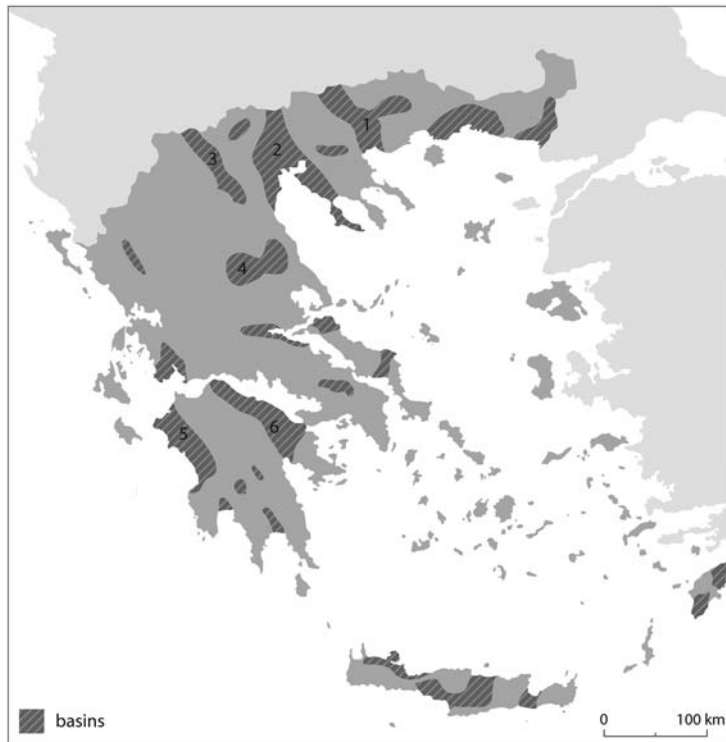


Fig. 6.11 The main Neogene-Quaternary basins of Greece; modified after Mountrakis 1985: figure 81. Note that most of the basins essentially follow the main structural trend (NW-SE) as inherited from the orogenetic axis of the Hellenides. 1) the basins of the Strymonas river, i.e. the Serres, Angitis, Strymonikos, Pieria and Akropotamos basins 2) the Axios river-Thessaloniki basin 3) the Florina-Vegoritiss-Ptolemais basins 4) the Larissa-Karditsa basins 5) the Pyrgos-Kyllini basins 6) the Argos-Korinthos-Xylokastro basins

lides 1993; Caputo *et al.* 1994; see above 4.6.2). A reorganization of the stress trajectories occurs in the southern Aegean (Angelier *et al.* 1982; Piper and Perissoratis 2003), whereas the north Aegean region experiences also a change in the direction of the stress field from NE-SW during Pliocene-Early Pleistocene to N-S from Middle Pleistocene onwards (Rondoyanni *et al.* 2004). A regional clockwise rotation of 10° that affected western Greece after 4 Ma (van Hinsbergen *et al.* 2005) appears to have taken place in Zakynthos during the last 0.77 kyr and is thought to be associated with concurrent uplift in mainland Greece, caused by rebound processes (Duermeijer *et al.* 1999; but see van Hinsbergen *et al.* 2006). Uplift is, for example, recorded in southwestern Peloponnese, where from Middle Pleistocene onwards the regime of subsidence gives way to a regime of uplifting blocks (Mariolakis *et al.* 1994; Papanikolaou *et al.* 2007). In the northern coastal areas of the Peloponnese, uplift became more intense from the mid-Middle Pleistocene onwards, when a third phase of the opening of the Corinth Gulf is thought to be initiated (Moretti *et al.* 2003; Sakellariou *et al.* 2007; see also below). In sum, during the early-middle Pleistocene (after *ca.* 1.0 Ma) there is a change in the direction of extension: in the

western part of the Hellenic arc and in central and northern Greece, the tensional stresses shifted from NE-SW to NNW-SSE, whilst the Gulf of Corinth was subjected to a rapid phase of rifting (Schattner 2010, 545). Convergence rates increased at the outer perimeter of the Hellenic arc, probably as a result of a short but intense compressional phase during 1.0–0.7 Ma that prevailed between the extensional periods (*ibid.*). Overall, this change is thought to be related with a major kinematic transition that affected the tectonic regime of the entire eastern Mediterranean region (Schattner 2010).

6.3.3 Geodynamic interpretation and geomorphological consequences

In the Late Pliocene-Pleistocene and during the course of the Quaternary, tensional stresses (re)appeared in many areas, causing further subsidence along new normal faults and/or pre-existing structures that were re-activated, as it is, for instance, the case for the Larissa basin in Thessaly (Caputo and Pavlides 1993) or the Florina-Ptolemais basin complex (Pavlides and Mountrakis 1987). The latter is also a good example of the way in which Quaternary tectonics formed hills and ridges that subdivided the

wider basin into several sub-basins, most of which occur now as fault-bounded lakes (*ibid*). In essence, most of these tectonically controlled basins (grabens) are bounded by still active faults, and they can be viewed -in geomorphological terms- as the key sedimentary basins, which served as depocenters for sediment accumulation. They are morphologically defined by major drainage courses (*e.g.* the Alpheios and Peneios rivers), lakes (*e.g.* the lake Trichonis) and shallow gulfs (*e.g.* Patras and Ambracian gulfs) (Doutsos and Kokkalas 2001; Caputo *et al.* 1994). Consequently, it is not surprising that the vast majority of Pleistocene sediments outcrop and/or are buried inside those basins (Mountrakis 1985). The most important Neogene-Quaternary composite basins of Greece are shown in Fig. 6.11.

Evidently, neotectonic⁵³ movements have been major controlling agents in the evolution of the present landscape and the distribution, preservation and visibility of the Pleistocene deposits. First and foremost, extensional tectonism dictated the number, structure, spatial extent and distribution of accommodation spaces for Pleistocene sediment accumulation. In contrast to compressional movements and the resulting 'shortening' of the landscape, the stretching of the land during extension favors the formation of such accommodation spaces. Compared to the situation in northern latitudes, where glacial and periglacial processes were both more widespread and more severe, the extensional tectonic regime in Greece facilitated the generation of landforms that were potentially suitable for protecting thick sedimentary sequences from climatically-induced erosional processes, as it is, for instance, manifested by the unique record of Tenaghi Philippon. Yet, records of this kind, with long and relatively undisturbed infills of terrigenous material, are mostly to be found in basins that are now submerged by the sea (*e.g.* on the northern borderlands of the Aegean and offshore Thrace) or occur at present as lakes (*e.g.* Ioannina lake).

Sedimentary basins are the chief means of the medium- to long-term preservation of the changing geological record, and tectonism exerts major controls on rates of sediment discharge through the effects of progressive uplift and subsidence (Leeder 1997), which in turn influence also the visibility of Pleistocene deposits within a sedimentary sequence (Leeder and Jackson 1993). Subsiding areas have been acting as sedimentary receivers, whereas uplifting blocks commonly served as source areas for sediment weathering and transport (*ibid*). In the case of subsided blocks, sediments may have been locally protected from erosion as long as they remained buried, and especially in stacked sequences; in this case, preservation potential is high, but archaeological visibility is low when sediments are deeply buried. Sediments that were originally deposited in subsiding/subsided blocks, were subsequently buried by younger deposits but at a later stage were subjected to uplift, may offer better visibility/accessibility if uplift-triggered erosion has removed their cover and exposed them; but at the same time they may offer little potential for preservation, depending on the time that has elapsed since their subaerial exposure. In the case of uplifting/uplifted blocks, sediments are undoubtedly more prone to erosional processes; hence they may provide low preservation potential but better visibility, again depending on the *timing*, *duration* and *intensity* of erosion: in case they were once buried, the ideal situation would be when erosion affects only the overlying cover, and archaeologists would like that to occur in relatively recent times, so that there are less possibilities for the target-deposits themselves to be subjected to erosion. Obviously, it all depends on sedimentation rates, their temporal relationship with tectonic movements, and the effects of the prevailing climatic conditions.

As in the rest of the Mediterranean (Macklin *et al.* 1995), the drainage basins in Greece can be divided in two main categories according to topographic settings: (1) steep-land fluvial systems above 500 m elevation, mainly involving rivers with steep, cobble-bed channels and high sediment loads and (2) basin and range drainages. Arguably, it is mainly the latter type that offers the potential for the development of depositional landforms (*i.e.* where archaeological finds may have been buried and preserved), in the form of alluvial fans, stacked sequences or extensive

53. The term "neotectonics" has not been rigorously defined; following Robertson and Mountrakis (2006), it is used here to refer to stress regimes that essentially remain active at present (broadly from Miocene to Recent in the Eastern Mediterranean region).

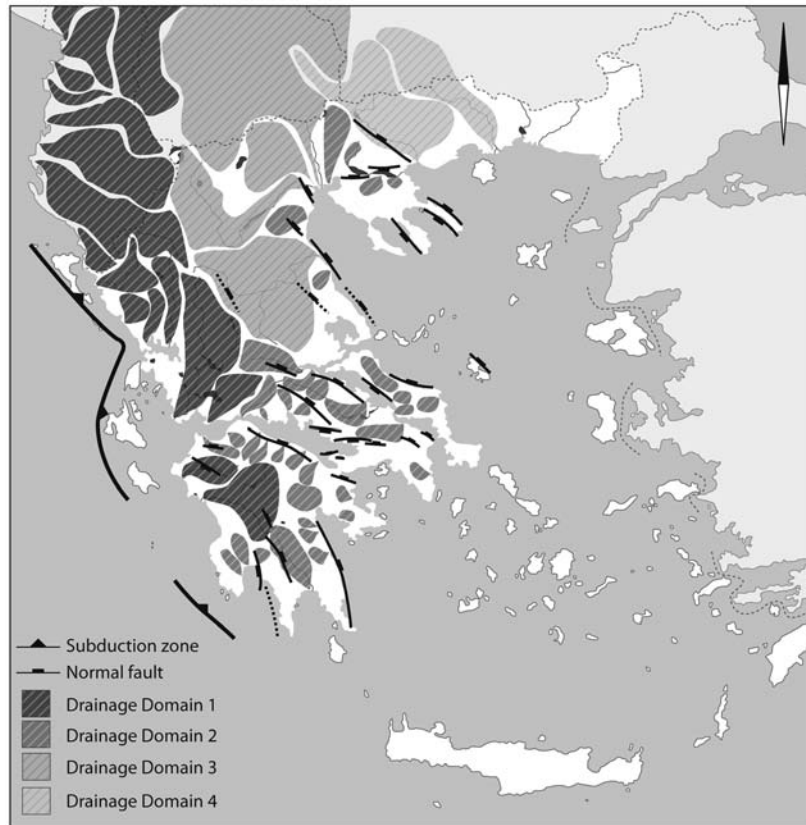


Fig. 6.12 Map of drainage domains in Greece, showing also some of the most important Neogene-Quaternary normal fault systems. The grouping was made according to regions in which drainage basins are broadly consistent in character, in terms of scale and predominant direction of flow. Modified after Collier *et al.* 1995: figure 1.

flights of river terraces. On the other hand, faulting and folding has generally constrained the development of extensive alluvial channel systems (Macklin *et al.* 1995) and Greece is lacking large basins comparable to other Mediterranean countries, such as those of the rivers Ebro (Spain), Rhône (France) or Po (Italy). In Greece, the size of the areas available for the development of drainage basins is controlled by fault spacing, fault overlap and by the tilting that results from extension (Collier *et al.* 1995). Moreover, the growth and form of drainage basins is largely influenced by the slopes, which, in the case of Greece, are often produced by normal faulting (in areas of extensional tectonics), subsequently modified by erosional and depositional processes that in turn relate to rock properties and the emergent relief (Leeder and Jackson 1993 with references therein; see also next section). For example, “the longer the initial tectonic slope, the greater the drainage basin area and hence the larger the alluvial fan area” (Leeder 1991, 456). Overall, footwall uplands exhibit short slopes that are drained by numerous small drainage basins, whilst hanging-wall depressions contain

larger slopes drained by larger, usually dendritic basins (Leeder and Jackson 1993).

On a large-scale perspective, the catchments of Greece can be grouped into four drainage domains, approximately corresponding to regions with a particular geological and tectonic history (Fig. 6.12; Collier *et al.* 1995). Drainage domain 1 covers western Greece, where, especially in its westernmost parts, thrusting, reverse fault reactivation of normal fault planes and strike-slip faulting control slope lengths and stream patterns (*ibid*). Here, Pliocene-Pleistocene compressional movements and the resultant crustal shortening (King and Bailey 1985) restrained the development of large basin systems. Drainage domain 2 consists also of small catchments, but this domain is the most tectonically active in Greece, and here the magnitude of the catchments reflect normal fault mechanisms (*e.g.* fault segmentation and fault spacing) produced by extensional tectonism (Collier *et al.* 1995; see below for particular examples). The third, north-central domain includes some of the largest basins of Greece, like the Mesohellenic molasse

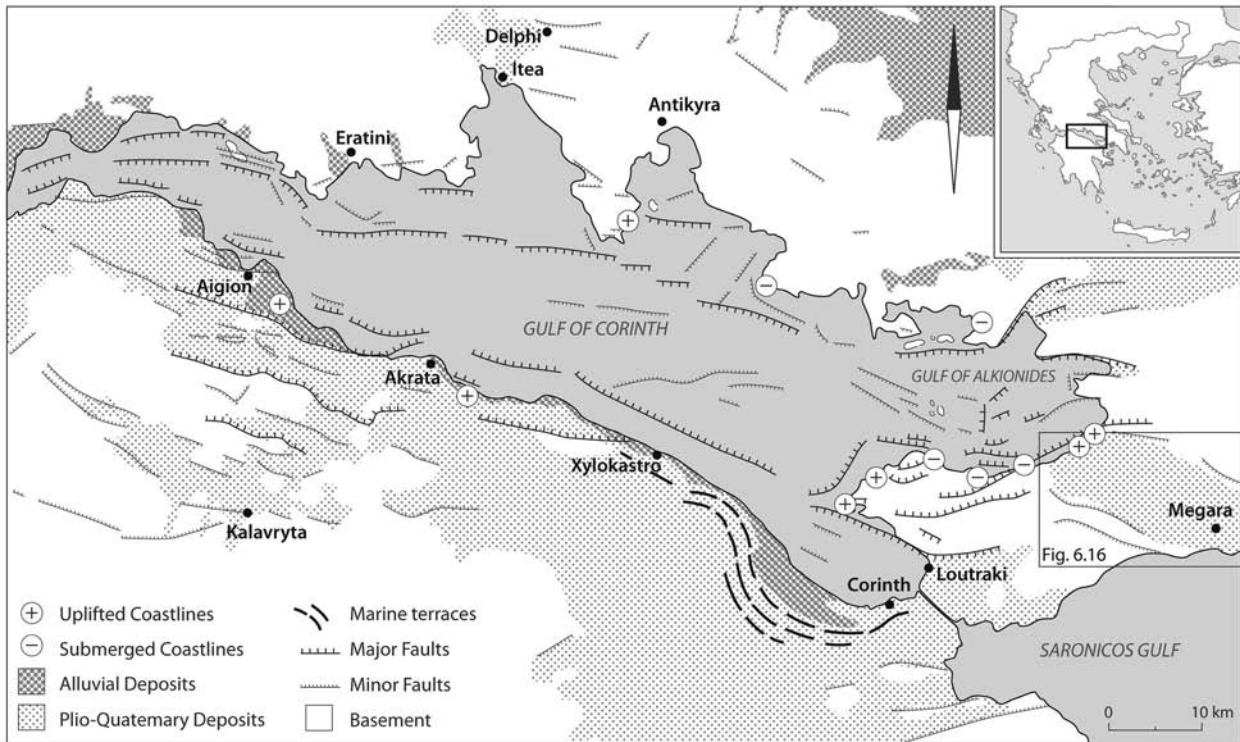


Fig. 6.13 Structural map of the Gulf of Corinth; modified after Moretti *et al.* 2003: fig. 1. Note the plus/ minus symbols indicating uplift/subsidence, and the uplifted marine terraces mentioned in text

trough and the basins of Karditsa and Larissa, which are, again, systems formed and controlled by tensional movements and normal fault geometries (Caputo and Pavlides 1993). The fourth domain occupies the north-eastern part of the country and involves large catchments that follow the axis of extensional basins, mainly parallel to the structural trend of the Hellenides (Collier *et al.* 1995). It has to be noted that the latter two domains, which overall host the largest catchments, experience significantly less tectonic movements than the former two domains, where intense tectonism dictated the small-scale development of basin systems (*ibid.*). As a result, the landscape of Epirus (domain 1) differs markedly from that of Thessaly (domain 3).

It is primarily these differences that are reflected in the divergences between Epirus and Thessaly, with regard to the degrees of preservation and visibility of the Early-Middle Pleistocene deposits and their associated Palaeolithic records. Due to the extensional tectonics that affected Thessaly in two main phases (Pliocene to Early Pleistocene, and Middle Pleisto-

cene to present), Early and Middle Pleistocene sediments are essentially restricted to areas that were uplifted and/or did not experience any subsidence (*i.e.* mainly the so-called Middle Thessalian Hills; Schneider 1968). In contrast, areas like the Larissa and Tyrnavos basins that were subsiding during the two phases, respectively, served as depocenters, in which sediments now are deeply buried. Consequently, uplift of the Middle Thessalian Hills made Early-Middle Pleistocene sediments archaeologically accessible at present (*i.e.* good visibility), but also exposed them to erosional processes and we therefore find them only as isolated patches that are discontinuous and fragmented in both their horizontal and vertical arrangement (*i.e.* low preservation). On the other hand, the story of the Palaeolithic sites in the rugged setting of Epirus is somewhat different. Here, tectonically-formed karst basins called *poljes* have acted as sediment traps that collected sediments from the surroundings, thereby concealing and preserving artefact scatters (*cf.* section 4.5). In this 100 km-wide, seismically active thrust belt zone, compressional movements were and still are prevailing,

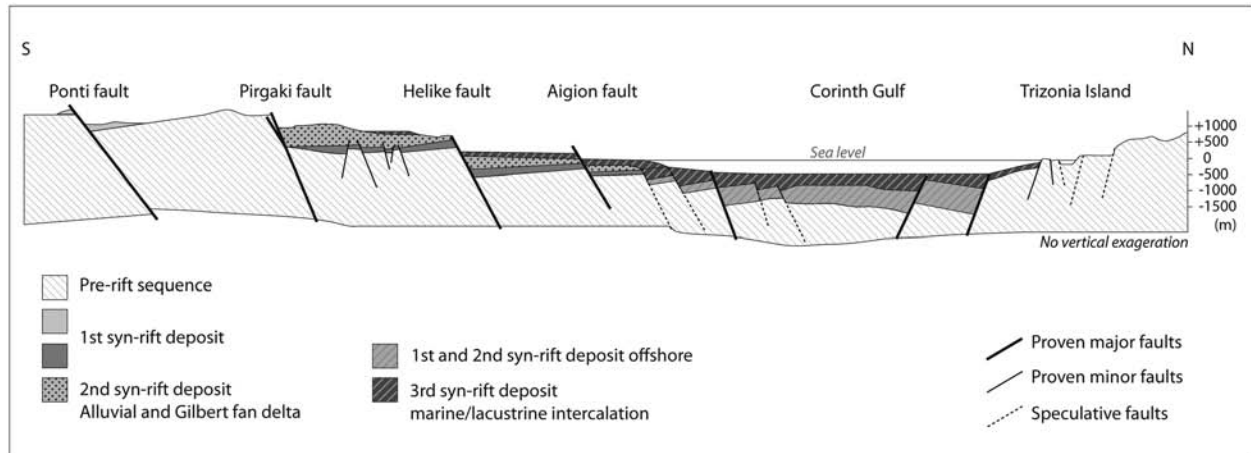


Fig. 6.14 Schematic cross-section of the Gulf of Corinth, The 1st, 2nd and 3rd syn-rift deposits largely correspond to the Lower, Middle and Upper Group of Rohais *et al.* 2007. Modified after Moretti *et al.* 2003: fig. 5

inducing considerably high uplift rates (King and Bailey 1985; King *et al.* 1993). Continuous and/or accumulated uplift has raised many of those enclosed tectonic depressions, forcing rivers to cut back upstream and capture the basins, draining former lakes and exposing the stratigraphy. Then again, whereas uplift, incision and basin dissection altogether assist the ease of site discovery, it also intensifies erosion, deformation and reworking of sediments, thereby enhancing the possibilities for the formation of archaeological palimpsests and/or secondary contexts.

We will now focus on the main tecto-sedimentary mechanisms which condition the above-mentioned interplay between low/high preservation potential and archaeological visibility of basin sediments. These mechanisms are essentially related to basin inversion, when parts of former sediment-receiving basins become uplifted and are turned into exhumed source areas (Mather 2009). In mainland Greece, the general trend of N-S extension is accommodated along E-W trending, sub-parallel normal faults, and within these systems, tectonic activity in each paroxysmic phase usually migrates from one system to another (Goldsworthy and Jackson 2001). When fault activity migrates, a basin that has been formed as the hanging-wall (downthrown block) of an old fault, may now become part of the footwall (upthrown block) of a new fault and hence be subjected to uplift, dissection and erosion (*ibid.*). As I argue later in chapter 7, the timing of uplift and basin inversion is

the most crucial factor in assessing the preservation/visibility of the Lower Palaeolithic archaeological record of Greece and it therefore deserves the thorough evaluation that is presented here with regard to specific cases.

Classic examples of fault migration and direct tectonic impact on Quaternary landscapes can be found in the area of the Gulf of Corinth (Mather 2009; Fig. 6.13). This is the most rapidly extending graben system in Greece and the most seismically active zone in Europe, with up to 1.5 mm/year of uplift rate at its southern margin since the late Middle Pleistocene, and a total minimum extension of 5.8 km over the last 1 Ma (Billiris *et al.* 1991; Lykousis *et al.* 2007; Leeder *et al.* 2008). The syn-rift sedimentary sequence is up to 2.4 Km thick (in the eastern and central part) and the greatest bulk of these sediments dates to the Pleistocene, with much of the sequence being younger than 1.0 Ma⁵⁴ (Moretti *et al.* 2003; Lykousis *et al.* 2007).

The timing of the initial phase of rifting ('Proto Gulf of Corinth') remains controversial, with proposed ages spanning the Pliocene to early Pleistocene (Ly-

54. The maximum mean sedimentation rate calculated for the depocenter of the central part is 2.7 m kyr⁻¹ and the 2.2 km-thick sequence below this part of the basin could have been accumulated within the last 0.8 Ma (Lykousis *et al.* 2007, 48).

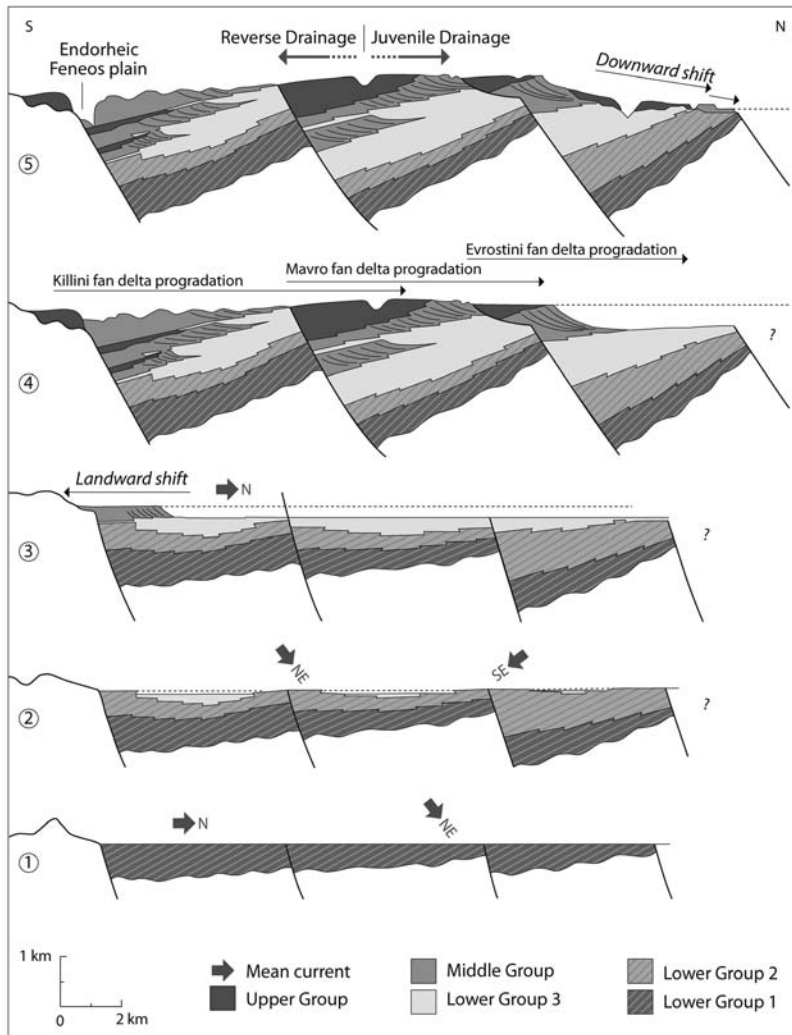


Fig. 6.15 Palaeogeographic and tectono-sedimentary evolution of the Akrata-Derveni area. Vertical exaggeration $\times 4$. Modified after Rohais *et al.* 2007: fig. 10

kousis *et al.* 2007; Rohais *et al.* 2007; Leeder *et al.* 2008); during this phase, deposition involved continental and shallow-water deposits (lacustrine-lagoonal, possibly alternating with marine sediments). The second phase of the opening started around 2.2 Ma (Leeder *et al.* 2008) or at *ca.* 1.5-1.0 Ma (Moretti *et al.* 2003; Rohais *et al.* 2007), it was marked by a dramatic increase of basin subsidence versus margin uplift and involved the development of giant Gilbert-type fan deltas along the southern margin (Lykousis *et al.* 2007). A third, most recent phase has been recently suggested, beginning around 350 and 120 ka in the eastern and western sectors respectively, according to the ages of the oldest-dated uplifted marine terraces (Moretti *et al.* 2003; Lykousis *et al.* 2007). Overall, current tectonism mainly involves the rapid uplift of northern Peloponnesus, namely the

southern part of the Gulf (*ibid.*). Due to the shallow depth of the Rio-Antirion sill in the western part of the gulf, and probably due to the Corinth Isthmus in the east (Lykousis *et al.* 2007), the gulf has been repeatedly transformed to a lake when the sea level fell below the level of the Rion sill, but these eustatic alterations are better-constrained only for the Late Pleistocene (Perissoratis *et al.* 2000).

The southern side of the gulf lies at the foot of a staircase of parallel, E-W trending normal faults that have been active mostly from the Quaternary to the present (Fig. 6.14; Goldsworthy and Jackson 2001). The marine terraces (see Fig. 6.13), which were cut during late Pleistocene sea-level highstands, are in the hanging-walls of the southern faults but have been uplifted (and thus preserved) for at least the last 300

kyr, as part of the footwalls of the coastal (offshore) faults, due to a basinward (*i.e.* northward) shift of faulting and sedimentation in the course of the Quaternary (*ibid*). The same phenomenon applies to the Plio-Pleistocene delta deposits, which are also part of these footwalls, reaching elevations of up to 1.75 km asl and thereby indicating considerable uplift (Fig. 6.14; Goldsworthy and Jackson 2001). The generic mechanisms of such a substantial uplift are still debated (*e.g.* Westaway 2007), and there might be also other causes besides footwall uplift (Goldsworthy and Jackson 2001). In any case, what needs to be stressed is the above-mentioned role of tectonism with regard to the exhumation, preservation and visibility of Pleistocene syn-rift deposits. The latter have recently been thoroughly researched in the Akrotiri region, where they are found in continuous outcrops that reach thicknesses of up to 2 km (Rohais *et al.* 2007). Below, the main results of these detailed studies (*ibid*; Rohais *et al.* 2008) are summarized.

The syn-rift deposits have been divided into three main lithostratigraphic units:

1. The Lower Group is mostly made of fluvio-lacustrine deposits, ranging in age from Late Pliocene to Early Pleistocene (*ca.* 3.6 to 1.5 Ma)
2. The Middle Group involves the above-mentioned, spectacular Gilbert-type fan deltas (see also Dart *et al.* 1994 for extensive descriptions), with subaerial lobes that range from 2 to 6 km in diameter, which are thought to have been formed during *ca.* 1.5 to 0.7 Ma. They mainly include conglomeratic facies up to 1 km-thick, much of which are coarse-grained deposits of high-energy environments, but floodplain fines and other fine-grained facies interpreted as lagoonal/lacustrine products, are also interbedded.
3. The Upper Group is composed of slope deposits, Gilbert-type deltas, stepped uplifted marine terraces along the coastline, as well as various fluvial terraces. This group is chronologically bracketed between *ca.* 700 ka to present.

Whereas the Lower Group records the initial stage of rift opening and the progressive flooding of continental to lacustrine environments (Fig. 6.15: 1-3), the transition of the latter to the Middle Group, which corresponds to the first occurrence of the giant Gilbert-type fan deltas, marks a significant tectonic

event and a major transgression, with increased fault displacements and fault-related subsidence providing the necessary accommodation spaces for fan deposition (Fig. 6.15: 3-4). During the accumulation of the Middle Group, the Gilbert-type fan deltas prograded northward into an alternating marine and lacustrine water body, and in several steps, following the basinward migration of the fault activity and the position of the depocenter.

Landward shifts of the shoreline indicate interruptions of those fan-delta progradations, related to changes in the balance between accommodation space and sediment supply. In places, perched river-terrace deposits overlie the syn-rift sediments, recording a multi-phase incision history and inversion of the direction of the palaeo-channels due to the uplift and southward tilting of footwall-blocks. A marked increase in surface uplift of the gulf's southern margin, together with a northward forced regression as the hinterland tilted southward, is documented by the Upper Group sediments (Fig. 6.15: 5). During deposition of the latter, uplifted and abandoned fans of the preceding Group were re-incised, and in some places, red soils developed upon such abandoned fans, indicating periods of relative stability and reduced sedimentation.

To sum up, Early and Middle Pleistocene sediments accumulated mostly (and originally) in the hanging-walls of normal faults, with sedimentation (mainly alluvial fan and delta formation) following the basinward migration of fault activity. While tectonic activity was migrating to the north, those sediments were being uplifted as parts of the footwalls of the newly-activated faults. Uplift resulted in fan abandonment and the initiation of stream dissection either by reversed drainage (due to the tilting of up-thrown blocks) or by new, juvenile drainage systems and headward erosion. Even if the southern faults were/are still active, the coastal faults are moving fast enough to keep their downthrown blocks below sea-level, whilst the southern faults are not (Goldsworthy and Jackson 2001, 492). As sedimentation occurred in pace with active extension, the depositional systems prograded at each stage, when sediment supply overwhelmed the creation of accommodation space (Rohais *et al.* 2007). The vertical stacking of the depositional sequences indicates an overall relative

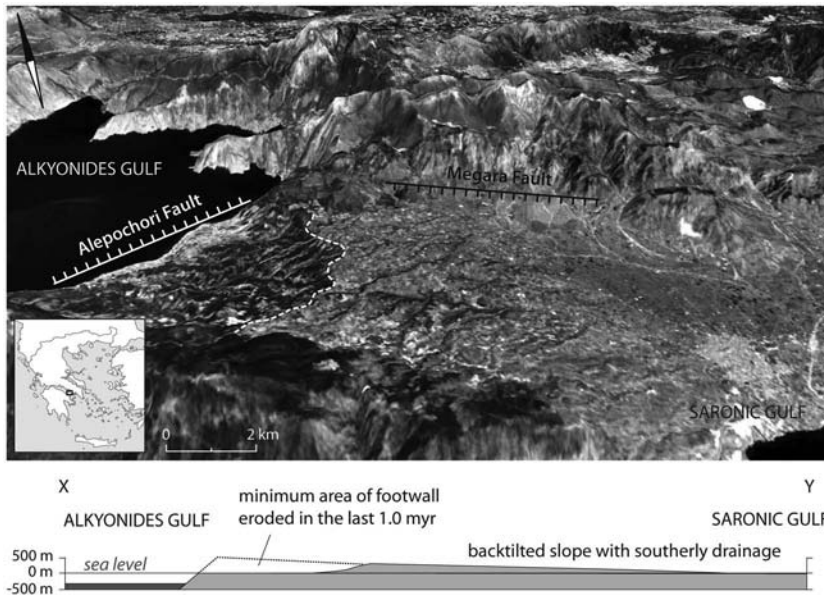


Fig. 6.16 Oblique view of the Megara basin showing the inactive Megara fault and the active Alepochori fault; the white dashed line marks the drainage divide mentioned in text. Vertical exaggeration $\times 3$, Landsat image from NASA World Wind. Inset: (modified after Collier *et al.* 1995: fig. 5) schematic section of the Megara basin from northwest (X) to southeast (Y), indicating the minimum amount of footwall erosion of the last 1.0 myr from the area defined by the drainage divide

base-level rise during deposition that would have been most probably dominated by hanging-wall subsidence (Dart *et al.* 1994, 558). Combined with apparently very high sedimentation rates, this kind of vertical aggradation quickly ensured protection from erosional agents, thereby providing a high degree of preservation. Subsequent (late Middle to Late Pleistocene until present) further uplift, abandonment and dissection facilitated the outcropping of the sediments in the form of large fan-sections, perched palaeo-valleys, and uplifted terrace deposits—in other words, a fairly good degree of visibility at present.

The Neogene Megara basin is today an inverted basin located at the eastern end of the Alkyonides Gulf (Fig. 6.16), and provides another example of how changes in tectonic activity influence the preservation and visibility of early Pleistocene deposits. Here, the sedimentary infill contains about 1.2 km of alluvial, fluvial and lacustrine deposits; most of the sequence dates to the Pliocene, with Pleistocene sediments being restricted to less than 80 m of the uppermost part of the infill (Leeder *et al.* 2008). When the basin was under extension during the Pliocene, it was the northeast-bounding Megara fault that controlled the contemporaneous sedimentary infill, imposing a dip of the sediments towards the northeast, at the hanging-wall of the fault (Goldsworthy and Jackson 2000). At around 1.0 Ma this fault died out and the orientation of tectonic activity changed, with activa-

tion of the Alepochori fault to the north-west (Leeder and Jackson 1993). The >300 m of footwall uplift along this -still active- fault reversed the previous, NW-draining Pliocene drainage system to the south of the footwall drainage divide, by back-tilting the former depositional surface towards the south-east (Collier *et al.* 1995).

If the Megara fault was still active after 1.0 Ma, subsidence of the basin would force the rivers to aggrade in order to reach a graded profile. Instead, due to the inactivation of the Megara fault and the activation of the Alepochori fault, uplift (of the Alepochori footwall) forced rivers to incise and erode the sedimentary infill. Stream patterns that were established in the uplifted block since 1.0 Ma have been mainly controlled by rock type: catchments draining the northern, active front of the footwall are small and steep (mean slopes $12\text{--}22^\circ$) due to the more resistant limestone and serpentinite bedrock; whereas larger, dendritic drainage systems have developed in the southern, back-tilted and poorly consolidated Pliocene and Pleistocene sediments, forming deeply incised gorges and badland-type terrains (Leeder *et al.* 2002). In the latter catchments, vertical cliff retreat predominates due to rockfalls, and undercutting ephemeral streams subsequently remove the debris (*ibid.*). Such rockfalls and slides at the headcuts of deep gorges have promoted a high rate of divide retreat (Leeder and Jackson 1993), which in turn re-

flects also a high amount of catchment erosion. In fact, it has been estimated that around 9 km³ of foot-wall sediments have been eroded, an amount that would be translated to a 180 m-thick layer deposited offshore over the Alkyonides Gulf (Mather 2009). It is thus not surprising that recent studies assessed a cumulative vertical throw of 1100 m between the subsiding Alkyonides basin depocenter and the uplifting Megara basin; notably, this total displacement probably took place over the period of the last 400–450 kyr (Sakellariou *et al.* 2007).

In sum, the change in tectonic activity around 1.0 Ma resulted in uplift of the basin, basin inversion, drainage diversion and high erosion rates from incising streams, as the depocenter moved out of the Megara basin and into the Alkyonides Gulf (offshore). We can therefore conclude that only sediments deposited in the basin *before* 1.0 Ma may still be locally preserved, potentially offering also a good degree of visibility where streams incise and expose them; on the other hand, after around 1.0 Ma, and especially after *ca.* 450 ka, erosion would predominate over sedimentation and hence it is very unlikely for sediments of that time-span to have been preserved. Indeed, an ash layer located at *ca.* 100 m below the surface and dated at ~ 2.8 Ma, and a calcrete member that caps the entire sequence and dates to around 0.77 Ma, altogether indicate that the topmost *ca.* 80 m of sediments (*i.e.* above the tuff and below the calcrete) are of Late Pliocene to Early Pleistocene age (Leeder *et al.* 2008)⁵⁵.

6.3.4 Discussion

The case-studies above illustrate how tectonism controls syn- and post-sedimentary processes that in turn influence preservation and visibility of sediments within sedimentary basins. Erosion, deposition and re-sedimentation of the sedimentary infill basically depends on the structure and evolution of drainage catchments, hence a focus was given to the manner in which tectonic forces determine the type, distribu-

tion and development of drainages. All of the examples outlined above show that basins can change from substantial subsidence to considerable uplift, erosion and re-deposition, all within one million years. This raises important implications with regard to preservation biases upon an archaeological record that has been produced within such a highly active tectonic setting. Temporal and spatial changes in tectonic activity and their derivatives, such as fault migration and basin inversion, were stressed in this regard, and yet there are numerous additional examples from Greek sites that reveal equally important tectonic signatures on landscape modification: among others, these would include changes in fault orientation, fault segmentation, block rotations, differential extension rates along strike, transfer-fault activity, relief rejuvenation and base-level control (Goldsworthy and Jackson 2000, 2001; Goldsworthy *et al.* 2002; Leeder 1991; Leeder and Jackson 1993; Mather 2009; Caputo *et al.* 1994; Macklin *et al.* 1995).

Due to the limited space available here, it was not possible to elaborate on another major tectonic agent of deformation and landscape instability, namely earthquakes, which constitute the ground surface expressions of tectonic movements that occur at depth. Earthquake-related deformation can result in surface faulting producing vertical (uplift and subsidence) and/or horizontal offsets of the surface (Stiros 2009). Seismicity is undeniably a crucial element of landscape evolution in Greece: based on an historical record of more than 2,500 years, it has been estimated that the mean occurrence frequency of strong earthquakes equals about one every 1.7 years (Papadopoulos and Kijko 1991, cited in Caputo *et al.* 2006).

Earthquakes are main controlling agents for an array of slope destabilization phenomena and gravitative mass movements, ranging from slow downslope creep and debris flows to rapid sliding of large masses (Ferentinos 1992). For instance, landslide distribution in the rift zone of the Corinth Gulf is consistent with the distribution of normal faults and the presence of tectonically highly sheared and weathered geological formations, whilst Neogene and Quaternary fine-grained and largely unconsolidated sediments are amongst the most critical landslide-prone formations (Koukis *et al.* 2009). Notably, tectonically-fractured clastic deposits, and sediments

55. In fact, the dating of this newly-discovered ash member may provide a maximum age of 2.15 Ma for the abandonment of the basin (Leeder *et al.* 2008, 136), instead of 1.0 Ma that was estimated by previous studies.

that have been subjected to mass failures in the past, are more likely to experience new gravitational collapses (*ibid*). Although earthquakes are obvious driving forces in such events, especially in areas with high density of epicenters, excessive rainfall is usually another interacting mechanism that can trigger large displacements (Sabatakakis *et al.* 2005). The role of precipitation (duration, intensity, recurrence intervals, deluges, etc) was examined in the previous chapter, and the role of lithology and rock properties is assessed in the following chapter. Besides the relations mentioned above with regard to tectonically-exerted controls, suffice it here to mention briefly other tectonic features that influence slope (in)stability, such as the presence of foliation, schistosity and cleavages resulting from moderate tectonic events, the presence of faults, folds, discontinuities and highly-fractured zones related to strong tectonism, and the occurrence of imbrications and overthrusts associated with even more intense tectonic movements (Rozos *et al.* 2008).

6.4 SEA-LEVEL CHANGES

6.4.1 Introduction

Two handaxes and a bifacial artefact, all attributed to the Lower Palaeolithic, were discovered in 1995 at a depth of 8 m below present sea-level offshore from the coast of Table Bay, South Africa (Werz and Flemming 2001), thereby providing palpable evidence for the importance of submerged landscapes and the potential for both preservation and recovery of maritime Lower Palaeolithic archaeological records (*cf.* Hosfield 2007; Bailey and Flemming 2008). Until recently, the prevailing notion in the archaeological discourse maintained that early hominins were unable to adequately exploit marine resources, while coastal adaptations were considered as peripheral in human evolution, essentially restricted to the times of the Upper Palaeolithic and onwards (*e.g.* Erlandson 2001; Bailey 2004; Westley and Dix 2006; Fa 2008; Bicho and Haws 2008). As new data progressively come to light, the earliest evidence for hominin use of marine resources is increasingly pushed back, to now include the Middle and even the Early Pleistocene (*e.g.* Marean *et al.* 2007; Choi and Driwantoro 2007). In this light, the interest in coastal landscapes has been lately renewed and this is justifi-

fied by studies that reveal the significance of those environments, as:

1. Areas of wider archaeological and palaeoanthropological implications, as potential sources of evidence for subsistence strategies and adaptations that might have prompted behavioral innovations (Erlandson 2001), for example with regard to sea crossings and the origins of seafaring (Anderson *et al.* 2010) or the use of marine resources mentioned above.
2. Potential refugia during periods of increased climatic stress, for plants (Médail and Diadema 2009; Rodríguez-Sánchez *et al.* 2008), animals (Hewitt 2000; Sommer and Nadachowski 2006) and hence probably also hominins (Carrión *et al.* 2008; Finlayson 2008), as areas with milder climates due to marine conditions and with valuable environmental resources, thus acquiring the status of super-ecotones (transitional ecological zones between terrestrial and marine environments), where a rich and diverse mosaic of habitats coexists over short distances (Bailey *et al.* 2008), providing water and food resources (Faure *et al.* 2002), or even shells for tool-production (Szabó *et al.* 2007).
3. Corridors of population movements (see *e.g.* Stringer 2000b; Derricourt 2005; Oppenheimer 2009).

Greece has the longest coastline in the Mediterranean, consisting of 13,780 km and including 6,000 islands and islets that make up around half of the country's coastline (<http://ec.europa.eu/maritimeaffairs>). It thus becomes obvious that a great component of geomorphological and geoarchaeological processes in the Greek territory has been critically influenced by sea-level fluctuations. While the palaeogeographic and palaeoenvironmental role of the coastal zones and the Aegean and Ionian Islands is also briefly discussed, the emphasis in this chapter is put on the geomorphological biases that the marine control has exerted upon the Pleistocene geoarchaeological record.

6.4.2 Sea-level changes: contributing factors and complicating perplexities

The level of the sea-surface relative to the adjacent land changes over time basically due to interactions

and feedbacks between climatic fluctuations, oscillations in the gravitational potential of the earth-ice-water system, as well as tectonic movements⁵⁶ (Lambeck 1996). Therefore, in order to understand, measure and model sea-level fluctuations, three main contributions have to be taken into account (*ibid*; Lambeck 2004):

1. *eustatic sea-level contribution*. As the ice sheets wax and wane, the volume of the water in the oceans decreases or increases accordingly, resulting in rising or falling sea-levels
2. *isostatic contribution*. (i) glacio-isostatic; the loading of the sea floor with meltwater from the decaying ice-sheets, or the removal of water-load when water is trapped as ice, deforms the surface of the planet, stresses the mantle and forces the crust to respond to this (de)compression, as its buoyancy is decreased/increased. This process, related to crustal rebound, is known as isostatic compensation. (ii) hydro-isostatic; because of this redistribution of ice-water mass and the deformation of the earth in response to mantle flow and surface deflection, the gravity field of the earth is changing, in turn modifying sea-levels: when ice sheets grow, gravitational attraction of the ice pulls the water towards the expanding ice dome and sea-levels rise near the growing ice margin, whilst they fall far from the ice. The total effect of (i) and (ii) is called glacio-hydro-isostasy.
3. *tectonic contribution*. This refers to tectonically active areas, where vertical tectonic movements are important.

The relative importance of each of the contributing factors is space- and time-dependent: for instance, sea-level changes during the last glacial cycle are primarily the results of changes in high-latitude continent-based ice volume, whilst present-day oscillations on centennial or annual time-scales are mostly of atmospheric and oceanographic origin (Lambeck 2004). In Greece, the predicted LGM sea-level for

Thrace (northernmost area) differs from the predicted value for Crete (southernmost area) by about 20 m, because the former is a continental margin site, whereas the latter lies further from the ice sheet and here the hydro-isostatic component is that of an island (Lambeck 1996). Complexities are not restricted only to the modeling of these contributions, *e.g.* when assessing crustal rheology (for the earth-model parameters), ice-sheet dimensions, advance and retreat (for the ice-model parameters), or tectonic histories; but include also the accuracy and the interpretation of the observational evidence, namely the geological indicators (*e.g.* age-height relations of marine solution notches, depths of submarine sediments and shorelines, beach deposits, marine terraces, sea caves and speleothems), biological indicators (*e.g.* coral reefs and mollusks) and archaeological indicators (*e.g.* submerged sites) (Fairbanks 1989; van Andel 1989; Flemming 1998; Bard *et al.* 1990, 2002; Lambeck 1996, 2004; Lambeck and Purcell 2005; Caputo 2007). Together with the three corrective terms (glacio- and hydro-isostasy and tectonic history), the latter indicators are used to calibrate sea-level curves when they are extrapolated from $\delta^{18}\text{O}$ -curves, because sea-level fluctuations are not a simple function of orbital forcing (Bard *et al.* 2002), the isotopic composition of ice-sheets varies with their size and latitudinal position (*e.g.* Clark and Mix 2002), and marine isotope values cannot be linearly converted into sea-level values (Bintanja *et al.* 2005). Thus, the estimation that a variation of 0.1‰ of the $\delta^{18}\text{O}$ corresponds to a variation of around 10 m of sea-level position (Shackleton 1987) is reported as commonly accepted (Caputo 2007), whereas a $\pm 1^\circ\text{C}$ of uncertainty in deep-sea temperature variations implies a confidence limit of about $\pm 30\text{m}$ on inferred sea-levels (Siddall *et al.* 2003). Overall, estimates of the uncertainty in sea-level positions presented in some of the latest-published global sea-level curves are in the range of ± 11 to 13 m (Rohling *et al.* 1998; Waelbroeck *et al.* 2002; Siddall *et al.* 2003; Bintanja *et al.* 2005). In considering such variances and the precision of sea-level predictions from the perspective of an end-user, Caputo (2007) compared various published curves and showed that positions (age and height) differ up to *ca.* 18 kyr and more than 35 m between different reconstructions (note that, as in this example the emphasis was given to major interglacial peaks, even the number of these

56. Needless to say, the processes, records and models related to sea level changes are altogether an issue too complex to be explained and/or reviewed here. The interested reader is thus referred to Lambeck 1995, 1996, 2004; Lambeck and Purcell 2005; Lambeck *et al.* 2002a; as well as the special issue of *Global and Planetary Change*, vol. 66, March 2009.

peaks was shown to differ from curve to curve). The implication of this comparison, as the researcher puts it, is that “if different end-users consider different sea-level curves to analyze the very same area where absolute ages are not available for all recognized inner edges [*i.e.* edges of shore platforms created by stillstands], firstly, different correlations between marine terraces and highstand sea-levels could be obtained, secondly, different ages could be attributed to the same terrace and, thirdly, the estimated uplift rates could vary significantly” (ibid, 422).

Notwithstanding these limitations in the level of accuracy, and after corrections for the isostatic and tectonic effects have been made, regional sea-level and palaeo-shoreline positions can be usefully approximated from global sea-level data “if we make no great demands on spatial or temporal resolution”, whilst “the uncertainty of palaeo-shoreline positions even on wide, almost level shelves would not exceed 10% of the width of the shelf” (van Andel 1989, 735). In view of the above and considering also the constraints imposed by the fragmented nature of the geological archive as well as the limits in the currently available geochronological techniques, it is not surprising that high-resolution observations and modeling of past sea-levels exist only for the last glacial cycle (*ca.* 130 ka to present); with the record being better constrained for the period following and including the Last Glacial Maximum (Shackleton 1987; Fairbanks 1989; Lambeck *et al.* 2002b; Siddall *et al.* 2003). It is thus now widely accepted that sea-levels dropped to about 120–135 m below present sea-level (b.p.s.l.) during the LGM (Clark and Mix 2002; Peltier 2002), with subsequent melting of the ice-sheets and rising of sea-levels starting at about 19,000 years ago and approaching their present-day levels at 7,000 years ago (Lambeck *et al.* 2002b). Earlier cycles were most probably characterized by similar fluctuations, at least back to *ca.* 900 ka and most likely back to the beginning of the Pleistocene, but with lower amplitude of variation (Bailey and Flemming 2008). Overall, during the extreme phases of glacial stages, sea-level was 125 ± 12 m b.p.s.l., with less extreme lowstands before 700 ka (Bintanja *et al.* 2005, 126). A record from the Red Sea (Rohling *et al.* 1998) yielded lowstand estimates of 120 (± 8) m b.p.s.l. for MIS 8, 122 to 134 (± 9) m b.p.s.l. for MIS 10, and 139 (± 11) m b.p.s.l. for MIS 12 (the

latter confirming Shackleton’s (1987) estimation that global ice volume during MIS 12 exceeded LGM values by some 15%). From the same study, the maximum MIS 5 sea-level was estimated at ~ 6 m above the present level, whereas during MIS 7 sea-level remained below that of the present-day; the MIS 9 highstand was from zero to 15 m above the present level, but the largest sea-level rise of the past 500 kyr followed the MIS 12 lowstand, when levels culminated in a maximum MIS 11 highstand of up to 20 m above the present sea-level (Rohling *et al.* 1998). Although the MIS 12–11 transition involves an extreme glacial (Shackleton 1987) and perhaps an equally ‘extreme’ -or at least ‘enigmatic’- interglacial (see *e.g.* Helmke *et al.* 2008), the rise of the sea-level from the lowstand of MIS 12 to the highstand of MIS 11 implies that ice-volume changes in Quaternary glacial-interglacial cycles were over 30% greater than would be expected on the basis of the last cycle alone (Rohling *et al.* 1998, 165).

6.4.3 Quaternary sea-levels and palaeogeography of Greece

Introduction

A significant number of geological studies have been published in the past few decades concerning the Aegean and Ionian Seas, the majority of which deals with the late Pleistocene and Holocene and involves research into the stratigraphical, sedimentological and palaeogeographical processes occurring on the continental shelf or in major basins, gulfs and river deltas (*e.g.* Stanley and Perissoratis 1977; van Andel and Lianos 1984; Collins *et al.* 1981; Cramp *et al.* 1988; Perissoratis and Mitropoulos 1989; Mascle and Martin 1990; Roussakis *et al.* 2004; Kapsimalis *et al.* 2005; van Andel and Perissoratis 2006; Anastasakis *et al.* 2006; Lykousis *et al.* 1995, 2005; Papanikolaou *et al.* 2007; Poulos 2009; Lykousis 2009). For their own research objectives, all of these studies touch upon sea-level changes, even if sometimes indirectly. Compared to this substantial contribution from earth-sciences, the involvement of relevant research from an archaeological perspective is admittedly small and has been mostly associated with the later periods in prehistory, from the Mesolithic onwards (*e.g.* Kraft *et al.* 1977). Although this picture could reflect research biases, underwater methodolo-

gical constraints, or the long-lasting pervasiveness of specific archaeological paradigms (*e.g.* the ‘broad spectrum revolution’; or, the emphasis on excavating caves versus open-air sites), Pleistocene archaeology has been largely missing from the related investigations – of course with notable exceptions by researchers that have been repeatedly bringing the subject in the discourse (*e.g.* van Andel and Shackleton 1982; van Andel 1989; Bailey 1992; Runnels 1995; Runnels and van Andel 2003; *cf.* Lambeck 1996, 607).

Such a relative neglect stems partly from the difficulty in establishing reliable reconstructions due to the paucity of ‘hard evidence’: there are no ^{14}C data on former sea-level positions of the latest lowstand to the present level, let alone the direct dating of sea-level markers indicative of glacial-interglacial cycles earlier than the last one (Perissoratis and Conispoliatis 2003). Researchers are thus forced to work primarily with archaeological and geological data that require a lot of corrections and usually provide the starting points for inferences and correlations, which, in turn, are inherently based on presuppositions that cannot be directly confirmed. Archaeological evidence, including chronological data, is numerous, albeit mostly (and most reliably) for the last four to five thousand years (see for example references in Flemming 1998 for publications of site inventories; Kraft *et al.* 1977). Geological data comes in the form of submerged depositional sequences, revealed for instance by borings and gravity cores (*e.g.* van Andel *et al.* 1990b; Roussakis *et al.* 2004), submerged lagoonal or terrestrial sediments and marine-solution notches (Lambeck 1995). An important geological marker is the present position of the Last Interglacial shoreline, because it has long been well-established that sea-levels were at that time near their present level (*ibid.*); hence, wherever this shoreline occurs within a few meters above the present level, it can be inferred that the area has experienced little vertical movements, as it is reported to be locally the case in the Gulfs of Messinia, Lakonia and Argolis (in Peloponnesus; Lambeck 1995). Overall, the identification of this shoreline makes it easier to distinguish between the tectonic and isostatic components, and to correct for the amount and continuity of tectonic rates (*e.g.* Lambeck 1996).

Middle and Late Pleistocene evidence and the first attempts at reconstructions

Van Andel and Shackleton (1982) were the first to publish a reconstruction of the late Quaternary palaeogeography of Greece and the Aegean, elaborating on the archaeological implications with regard to coastal plain resources and migration routes. Notably, they were also the first – and the last – to provide an account of the estimated loss of coastal zone due to the rising sea-level in a given area (in their example, the southeast Argolid; *ibid.*). Later, van Andel and Lianos (1984) were able to pinpoint the sea-level position of the last glacial maximum on the shelf of the southern Argolid by using seismic profiler records: the lowstand level was recognized at a depth of -115 to -118 m as a sedimentary surface of a former subaerial coastal or river plain. Notably, the landward continuation of this LGM alluvial reflector could be traced also on land. This study offered the first ‘direct’ evidence for the identification and reconstruction of submerged Aegean palaeo-surfaces, foreshadowing the importance of seismic reflection profiles – among other marine geophysical techniques – as a powerful tool for coastal palaeogeography. Regressional or transgressional surfaces of the Late and late Middle Pleistocene have also been identified as unconformities that provide important chronostratigraphic markers. In the Gulf of Gokova (southeastern Aegean, off Turkey), four major erosional unconformities were correlated with the transgressions of MIS 9, 7, 5 and 1, when deltas rapidly retreated landward and little sedimentation took place on the shelf (Uluğ *et al.* 2005). Elsewhere, unconformities that were identified in seismic stratigraphic units indicated subaerial surfaces during glacial lowstands, as it is the case in the North Euboean Gulf (van Andel and Perissoratis 2006). In cores retrieved from South Euboean Gulf and the Gulf of Kavala, such unconformities have been identified as truncated B horizons of soils that were formed when land was exposed during lowstand(s) (Perissoratis and van Andel 1988; 1991). Similar soil horizons have been identified in boreholes onshore at the Argive Plain and on seismic reflectors offshore (van Andel *et al.* 1990b). These Middle and Late Pleistocene paleosols were formed on transgressive marine deposits when the shelf was exposed during glacial (regressive) intervals and they could be traced also

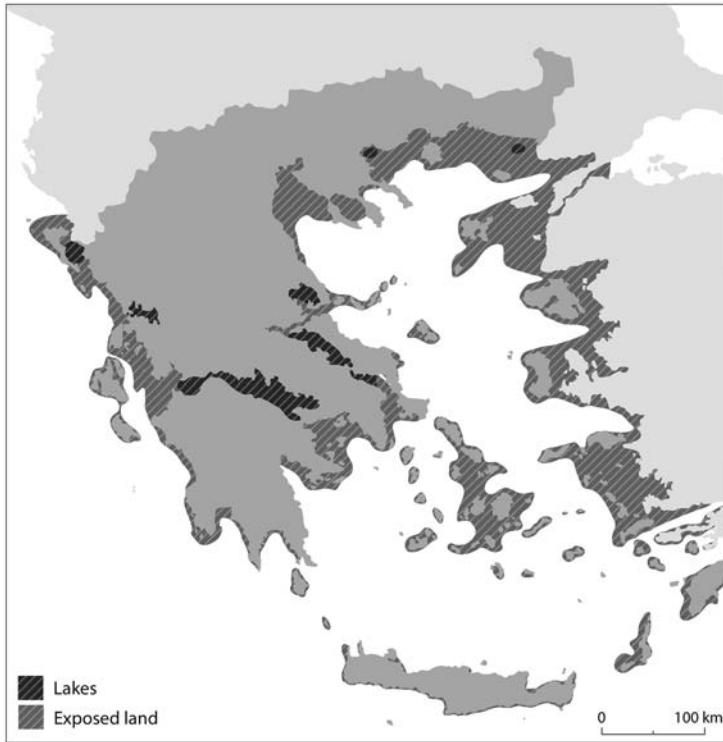


Fig. 6.17 Reconstruction of coastal configuration at the sea-level lowstand of MIS 2 (sea-level at -120 m). Modified after Perissoratis and Conispoliatis 2003: fig. 3

inland (ibid). Their landward extension facilitates correlations of sea-level changes deduced from the marine depositional record with Pleistocene surfaces inland; if they can be dated, they may offer valuable insights on the time-spans during which the shelf was exposed.

The exposure of coastal areas would attain its maximum extent only during glacial maxima and hence for only a few thousand years. Lambeck (1995, 1996) produced the first thoroughly-studied curve of Aegean sea-level change and shoreline evolution for different time-slices of the last 20 kyr, correcting for the glacio-isostatic and tectonic effects. For the period of the last glacial, Lambeck showed that coastal plains were fully exposed from about 20 to *ca.* 16

ka, whereas from *ca.* 70 ka up to the onset of the LGM, sea-levels fluctuated between about -50 and -80 m (1996, 606). Notably, the latter values (from -50 to -80 m) seem to be characteristic for the longest parts of the Middle and Late Pleistocene (Shackleton 1987). Lambeck's results (ibid) were generally confirmed by the study of Perissoratis and Conispoliatis (2003), who used a global eustatic curve for the last 20 kyr, corrected for the glacio-isostatic and tectonic contributions with the aid of sedimentary, bathymetric and seismic profile data (Fig. 6.17).

This map offers a first visual approximation of the maximum extent of exposed coastal areas during the Last Glacial Maximum, and hence it provides also a means of envisaging how much of the (potential) ar-

Depth of Continental Shelf	Area (km ²)	% in relation to mainland Greece
0 – 50 m	20,159	15.3
50 – 100 m	21,240	16.1
100 – 120 m	7,496	5.7
0 – 100 m	41,399	31.4
0 – 120 m	48,895	37.1

Table 6.1 Estimates of the extent of exposed coastal areas at different depths of lowered sea-level during the last glacial period (see text). The last column on the right shows the percentage of exposed areas when compared with the total extent of mainland Greece, which is 131,957 km². Data provided by V. Kapsimalis, personal communication 2009

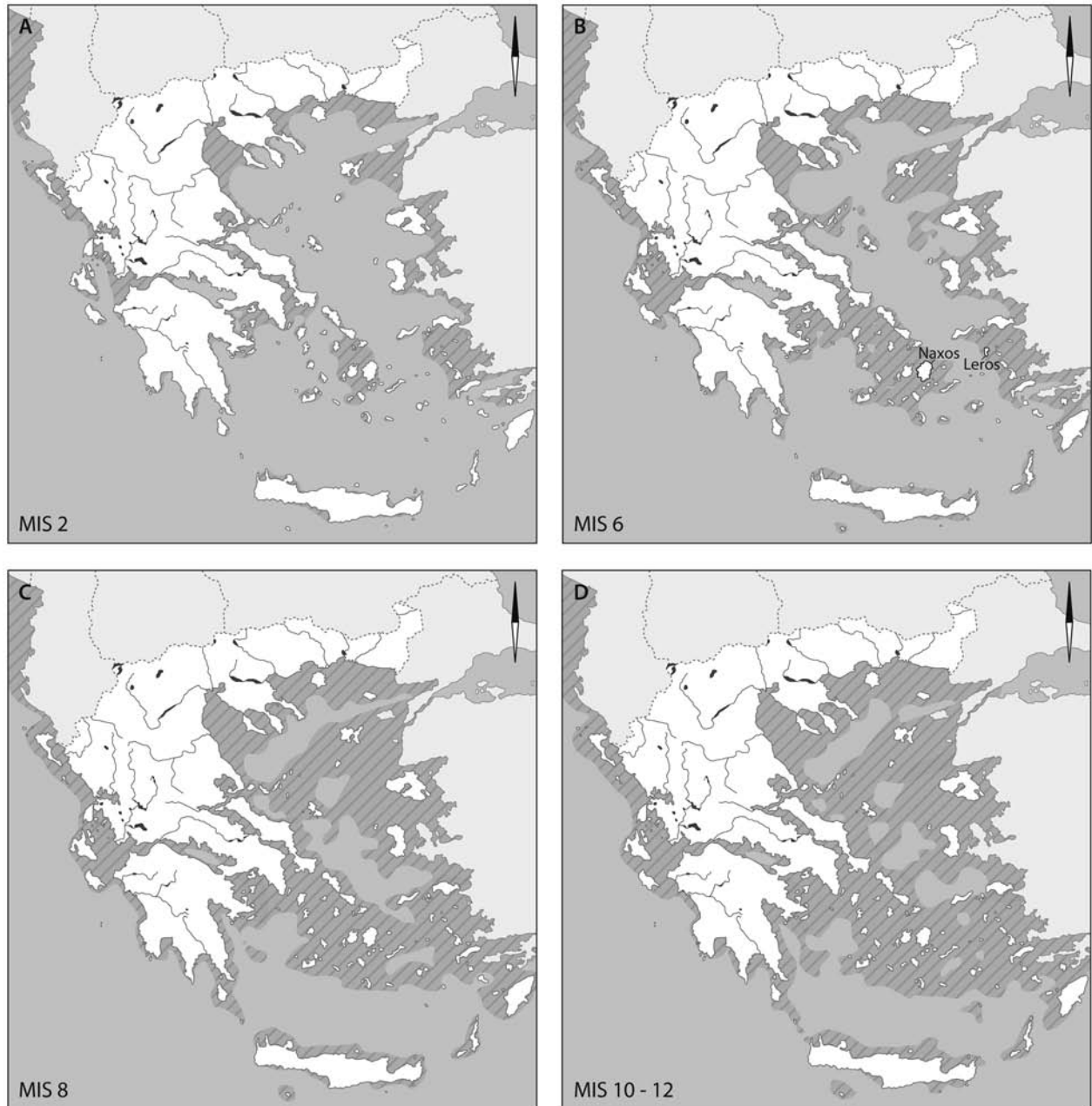


Fig. 6.18 Palaeogeographic reconstruction of the Aegean and the Ionian Sea for MIS 2, 6, 8 and 10-12. Hatched areas denote emerged land. Modified after Lykousis 2009: fig. 5

chaecological record lies submerged since the inundation of those areas. Table 6.1 gives a numerical appreciation for the loss of land during the last glacial period, though considering only the eustatic contribution and without accounting for the glacio-isostatic and tectonic effects. Nevertheless, these values give a fairly close approximation of the true extents of ex-

posed surfaces, being also *minimum* estimates for many of the areas depicted here, as the glacio-isostatic effect would give a correction in the order of only a few meters and because the subsidence that has occurred up to the present has not been taken into account (*cf.* Perissoratis and Conispoliatis 2003, 149-150; Lambeck 1995, 1996).

Area	Sites	MIS 6 - 2 (m ka ⁻¹)	MIS 8 - 6 (m ka ⁻¹)	MIS 10 - 8 (m ka ⁻¹)	MIS 12 - 10 (m ka ⁻¹)
NORTH AEGEAN	Thermaikos margin	0.86	1.43	1.61	1.88
	Northern margin	0.85	1.31	1.49	
	Southern margin	0.83	1.34	1.46	
CENTRAL AEGEAN	South Limnos margin	0.49	0.67		
	North-west Lesvos	0.53	0.71		
	West Lesvos	0.50	0.74		
	East Skyros	0.45	0.59		
	Eastern Cyclades	0.34	0.57		
	North-eastern Cyclades	0.40	0.55		
	Saronic Gulf	0.42	0.60		
	Corinth Gulf	0.70	1.28		
	Gulf of Patras	0.90			
	Izmir Bay	0.45	0.55		

Table 6.2 Subsidence rates for the Central and North Aegean margins during the last 400 kyr, after Lykousis 2009

Thus, considering -120 m as a mean value for the LGM lowstand (Lambeck 1995, 1996; Perissoratis and Conispoliatis 2003; van Andel and Lianos 1984), we can estimate a total of 48,895 km² of exposed coastal areas, or, certainly no less than 41,399 km². Even when regarding those as maximum and minimum values respectively, both of them correspond to more than a third of Greece's continental (mainland) coverage. This is admittedly a coarse estimation, but arguably within reasonable confidence limits (*e.g.* see van Andel and Shackleton 1982, 448; van Andel 1989, 735), bearing also in mind the accuracy levels discussed in the beginning of this chapter. The amount of exposed areas remains noteworthy (an equivalent of *ca.* 10% of the extent of the mainland) even when considering the value of -40 m, which would be the level that best defines the coastal palaeogeography of *ca.* 110 to 30 ka (van Andel 1989, 739); and this amount of exposed areas would again be raised appreciably if we consider the levels of -60 to -70 m as better representatives for the most severe stadials of that time-span (*ibid*).

Lower and Middle Pleistocene Aegean palaeogeography

Notwithstanding the importance of these Late Pleistocene reconstructions, the Aegean palaeogeography changes dramatically in the Middle and Early Pleistocene, when the subaerially exposed areas were three to five times more extensive than those of the Last Glacial Maximum. The key-factor behind this

large difference is the greater intensity of the extensional tectonism and the associated subsidence rates that affected the region during the earlier parts of the Pleistocene (Lykousis 2009).

After an early Pleistocene episode of compressional tectonics (Mercier *et al.* 1976), the extensional tectonic regime continued to be prevailing in the Aegean during the Middle and Late Pleistocene (see section 6.3). The subsidence rates that were associated with this latter regime during the last 400 kyr have been recently investigated by high-resolution seismic reflection profiles taken from selected sites in the Aegean (Lykousis 2009). The seismic profiles enabled the identification of successive peak glacial delta prograding sequences (Low System Tracts, 'LST'), which indicate the positions of glacial sea-level lowstands and palaeo-shelf edges with an error margin of less than 10-15 m (*ibid*). Assuming similar magnitudes for the different sea-level lowstands, and considering that the lack of hiatuses and the conformable development at increasing depths suggests continuous subsidence, the rates of subsidence were estimated by comparing the vertical displacement from the topset-to-foreset transitions (*i.e.* shelf-breaks) of every two successive LST prograding sequences (*ibid*; Table 6.2). Accordingly, the recognition of those palaeo-shelf break delta deposits together with the derived estimates of subsidence allowed the reconstruction of the Aegean palaeomorphology for the most pronounced glacial periods of the last 400 kyr (Fig. 6.18).

Lykousis notes that “during the isotopic stages 8, 9, 10, 11 and 12, almost 50-60 % of the present Aegean Sea was exposed to subaerial conditions [...] while marine conditions prevailed in the southern Aegean throughout the study period” (ibid, 2041). One first important implication that can be derived from those reconstructions is that, for the studied period (*i.e.* back to *ca.* 500 ka), the emergence of subaerial surfaces was not restricted only to the glacial stages but occurred also during some interglacials, notably those of MIS 9 and 11, but possibly also 7.

The lower subsidence values for the central parts of the Aegean are largely attributed to the relatively milder tectonic activity experienced in those areas, in comparison to the northern and southern parts (Lykousis 2009). Therefore, there are spatial differences in the Aegean subsidence rates (Table 6.2), with the highest values occurring in the seismotectonically active margins of the Gulfs of Patras/Corinth and the North Aegean. Importantly, there are also temporal differences: mean subsidence rates were reduced more than 50% over a period of *ca.* 300 kyr, reflecting a gradual decrease of the mean subduction rates (ibid). This is explained as the result of a gradual decline in the intensity of extensional tectonism and/or a decrease in the isostatic rebound after the early Pleistocene compressional phase in the Aegean domain (ibid).

On account of the results from this research as well as of correlations with evidence from commercial boreholes, Lykousis argues that the first marine transgression in the North Aegean probably occurred during the interglacial period of MIS 9 (Lykousis 2009, 2041). In the central Aegean, the absence of delta prograding sequences older than *ca.* 400 ka probably indicates that *before that time the area was a subaerially exposed land* (ibid). An earlier study by Lykousis and colleagues identified in the South Ikaria basin three delta progradation sequences, correlative to MIS 2, 6 and 8; a possible fourth (and probably a fifth) deformed and eroded deposit was then assumed to be of Early-Middle Pleistocene age (MIS 16-22), indicating “progradation in a shallow marine environment” (1995, 69). In light of the new data discussed above, this latter sequence of the South Ikaria basin should be viewed as probably reflecting lagoon-lacustrine conditions (or, at least not open

marine) at some time during the Early Pleistocene. This is most likely because directly to the south of the South Ikaria basin there is an important marine corridor between approximately the islands of Naxos and Leros. As we can see in Fig. 6.18 (B, C) this passage is closed (*i.e.* becomes subaerially exposed land) for the last time in MIS 8. As a result of the ‘closure’ of this marine corridor, the sea would not penetrate into the central and northern parts of the Aegean prior to about 400-500 ka (MIS 10-12) and all major depressions (basins) would have turned into lakes. Overall, the absence of prograding sequences deeper than those correlated to MIS 10-12, together with other sedimentological and biostratigraphic data, points to the conclusion that *at around MIS 8 and 10 as well as before ca. 500 ka the central and northern Aegean would have been a subaerially exposed land, with shallow water lake environments occupying the Aegean basins* (Lykousis 2009). Certainly, more data are needed in order to securely confirm this assessment and to constrain a lower limit for the time-span that most of the Aegean region was subaerially exposed. Nevertheless, most of the evidence available up to date seems to support this conclusion; yet, the low resolution of the chronological estimates prevents at the moment any substantial qualitative refinement⁵⁷ (*cf.* Anastasakis *et al.* 2006; Piper and Perissoratis 2003).

57. As noted above, Lykousis argues that prior to *ca.* 500 ka the central and northern Aegean areas would have been subaerially exposed land, without pinpointing the lower age-limit for the time-span of this land-exposure. His conclusion would be falsified if marine deposits dating to, for example, 700-800 ka were identified in the places where he denotes subaerially exposed land (*e.g.* as in Fig. 6.18: D). To assess this at present is difficult, because: (1) Lykousis’ maps are (inevitably) published in small scale (low resolution), thereby hampering comparisons with other published local seismic sections (published in larger scale, better resolution) (2) in lack of absolute dating, regional seismic stratigraphies are often chronologically bracketed by indirect methods: for instance, Piper and Perissoratis (2003) use sedimentation rates with error margins that may be as great as $\pm 50\%$ on ages >500 ka (3) unconformities are often used as both stratigraphic markers and chronostratigraphic tie-points for local/regional correlations and comparisons, but the time-span of erosion/non-deposition that those unconformities may represent is in most cases ill-defined or indefinable (4) ascribing a precise classificatory term of sedimentary facies to a reflector may be a difficult task, and thus a reflector characterized as “shallow marine” may actually be a lagoon facies.

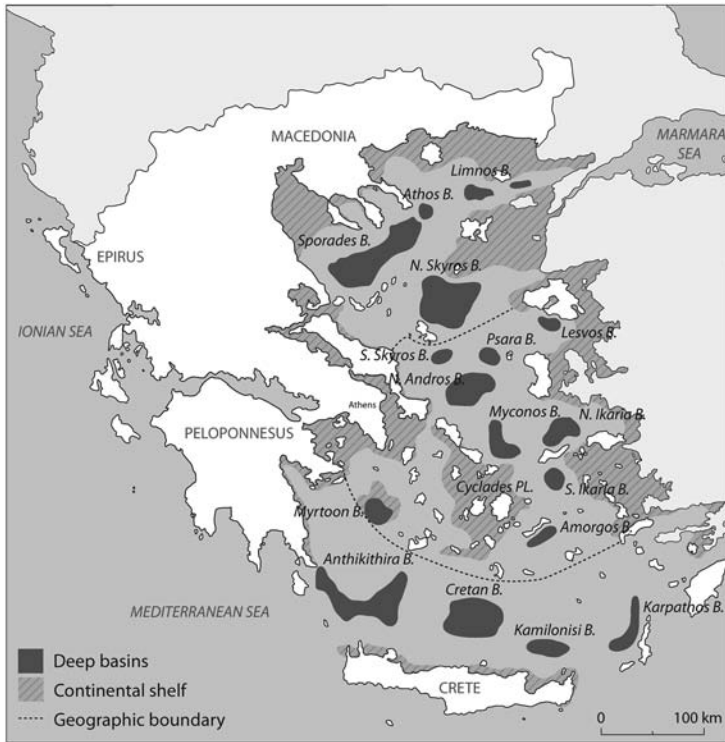


Fig. 6.19 Bathymetry of the Aegean Sea. B = basin, Pl. = Plateau. Dotted lines denote the boundaries of north, central and south Aegean. Modified after Poulos 2009: fig. 1

6.4.4 Prospects of underwater and terrestrial investigations of the Aegean Lower Palaeolithic record

The geomorphological and depositional setting

For both onshore, coastal areas, and offshore, sea-floor and sub-bottom deposits, a geoarchaeological prospecting of the most promising locations for retrieving Lower Palaeolithic evidence needs to take into account two critical factors: (1) sediment thicknesses and (2) geomorphological processes related to the construction/destruction of depositional land-forms. In order to evaluate both of these parameters, the Aegean region can be assessed on the basis of a geomorphological division into the following main settings: basins and troughs (depressions), plateaus (flat-topped sea floors) and ridges (long, narrow elevations with steep sides and irregular topography) (*cf.* Stanley and Perissoratis 1977).

From a large-scale perspective and on the grounds of the region's geodynamic/structural setting, physiographic/bathymetric morphology and sedimentological composition, the Aegean Sea can be divided in three main sectors (Mascle and Martin 1990; Poulos

2009): the northern, central and southern Aegean (Fig. 6.19). The *North Aegean* sector is characterized by almost aligned and relatively deep depressions, of which the North Aegean Trough is the most prominent and with the thickest sediment accumulation (Mascle and Martin 1990). Thinner sequences that tend to thin landward cover the three major plateaus of Thermaikos, Thasos-Samothraki and Limnos-Imvros, which extend up to a water depth of *ca.* 150 m and do not present any significant internal deformation (Stanley and Perissoratis 1977; Poulos 2009). The main morphostructural unit of the *Central Aegean* domain is the Cyclades Plateau, which is a largely aseismic and shallow region with water depths of less than 250 m. (Mascle and Martin 1990; Lykousis 2001; Poulos 2009). Here, the thickest sections of unconsolidated sediments occur in the basins, whereas sedimentary sequences are relatively thin (*ca.* 250 m) on the two plateaus (Cyclades and Samos-Kos), but more variable on the ridges of Andros-Chios and Amorgos-Leros (Stanley and Perissoratis 1977; Fig. 6.19). The *South Aegean* region includes the deepest depressions in the Aegean. Apart from the inner Argolikos Gulf (depths <600 m), the rest of this domain is composed of separate

sub-basins which altogether belong to the Cretan Sea (Poulos 2009).

The continental shelf of the Aegean is wide (*ca.* 25–95 km) along the northern and eastern coasts, where large rivers from the Balkans and Asia Minor have formed broad alluvial plains with thick terrigenous sedimentary sequences that make up a smooth morphology of low slope gradients (Perissoratis and Conispoliatis 2003). Those coastal alluvial plains extend seaward until water depths of about 120–140 m, where a distinct shelf-break occurs (*ibid*). In contrast, on the coastal zone of Western Greece⁵⁸, the eastern coast of Peloponnesus and the fringes of *ca.* 200 islands, the continental shelf is mostly narrow (<10 km) and rocky; in those cases the shelf break is largely controlled by major bounding faults and it occurs at depths of 130–150 m, beyond which very steep slopes (up to 1:20) lead into deep basins (Aksu *et al.* 1995).

Overall, the Aegean region has been intensely fractured due to tectonics, resembling now “a tectonic puzzle made up of relatively small pieces” (Muscle and Martin 1990, 276), with a complex topographical structure and an irregular bathymetry (Stanley and Perissoratis 1977). At places, notably in the central Aegean, depositional trends are not following closely those of topography, and -for example, in the Myrtoon Sea- the relationship between sedimentary/depositional patterns and physiography is not everywhere self-evident, with sedimentary infills varying markedly in terms of facies and thickness even in adjacent basins (*ibid*; Anastasakis *et al.* 2006). Nevertheless, the distribution of Pliocene/Quaternary deposits generally conforms to topography, so that the thickest sequences occur in depressions, whilst thinner deposits are found on plateaus and ridges and between basins and topographic highs (Stanley and Perissoratis 1977). As with their terrestrial counterparts, the now-submerged depressions and basins that served as sedimentary receivers are expected not only to contain the bulk of the preserved archaeolo-

gical evidence, but also to carry the best potential for yielding evidence in primary contexts. Yet, since the latter have subsided and are the places with the thickest sedimentary sequences, Early and Middle Pleistocene deposits are practically inaccessible by any contemporary technological means, as they lie in great depths and are usually buried under hundreds of meters of sediments (see further below). Thinner depositional sequences are to be found on plateaus and ridges, and areas with shallower water depths such as the Cyclades Plateau or the continental shelf of northern Aegean should be considered as main targets for future underwater investigations, especially in localities where the Holocene sediment tracts are of minor thickness (*cf.* Perissoratis and Conispoliatis 2003). As in the case of continental Greece (see chapter 6.3), areas that were basinal during Early Pleistocene may have turned into positive features (*i.e.* ridges, horsts) during Middle and Late Pleistocene due to basin inversion (*e.g.* see Piper and Perissoratis 2003), a fact possibly resulting in erosion of overlying deposits and exposure of the deeper (Early and/or Middle Pleistocene) strata. This kind of localities could also be deemed as potential targets, although their occurrence would be rather rare and their recognition difficult.

A geoarchaeological perspective

After pinpointing the most promising areas, submarine explorations need to apply certain oceanographic techniques, such as high-resolution reflection surveying, side-scan sonar surveying, bathymetric mapping, magnetometer surveys, etc (*e.g.* Ballard 2008). Yet, in all probability, these methods help only to identify the appropriate deposits and provide geomorphological indications for places where sites are likely to occur. Remote-sensing techniques are still not able to distinguish cultural (Palaeolithic) remains from natural features, and for this purpose visual methods must be used (*ibid*). Diving is, then, indispensable, and it commonly needs to be combined with extensive coring (Flemming 1998). Flemming (1985, 1998) reports on Levallois-Mousterian lithic debitage identified by diving in shallow waters (3 to 30 m) about 200 m off the coast of Kerkyra (Ionian Islands). Nonetheless, diving with the aim of identifying Lower Palaeolithic artefact scatters is virtually not yet a feasible research task for most of the Ae-

58. Strictly speaking, the coastal zone of western Greece belongs to the Ionian Sea. Following the researchers cited here, it is included in this discussion for the sake of meaningful comparisons.

gean, because the targeted deposits have been tectonically subsided to great depths. Moreover, erosion and partial or total disturbance of coastal zones and/or submerged depositional landforms should also be kept in mind: submarine mass movements, ranging from debris flows to large landslides, fault-related over-steepening of slopes and subsequent slope instabilities and failures, are altogether a wider and relatively well-documented reality in the Aegean (*e.g.* Lykousis *et al.* 2002, 2009; Xeidakis *et al.* 2007). This kind of phenomena that overall induce destruction or at least fragmentation of the marine geoarchaeological archive would have been accelerated by the alternating transgressive and regressive cycles. Considering also the complex tectonic history of the region (Jolivet and Brun 2010) –a fact that has obscured, biased and hampered Lower Palaeolithic research first and foremost on terrestrial Greece– one would be forced to conclude that the exploration of submerged terrestrial Pleistocene sites in the Aegean is far from being realistic in the near future; let alone the difficulties in convincing funding agencies for investing in surveys with admittedly little prospects for delivering solid results.

In that respect, perhaps the most promising and/or most realistic research objective would be the development of underwater research plans as parts of broader land-based investigations, or alternatively, as the seaward extensions of terrestrial explorations. These can include the regions of wide continental shelf mentioned above, namely the northern and eastern Aegean coastal areas, as well as the shallow-water area of the Cyclades Plateau and associated islands. The Cyclades have already been the target of geoarchaeological explorations, although with a primary focus on the late Upper Palaeolithic and later prehistoric periods (for a recent study and review see Kapsimalis *et al.* 2009). The latest approach (*ibid.*) concluded that the Cyclades Plateau cannot be considered as an area of high archaeological potential with respect to the Middle and Upper Palaeolithic, because preservation of material is not favored due to erosion, and access is impossible due to deep burial. Acknowledging the limitations outlined above, it is believed here that the Cyclades landmass (*i.e.* the C. Plateau *sensu stricto* plus the surrounding islands) should be regarded as an area with an archaeological potential that ought not to be overlooked, for the fol-

lowing main reasons: (1) for a vast amount of time –that may prove to reach even a million years– this was a terrestrial landscape, favorable to be used as not only a landbridge for animal and human migrations between Asia Minor and continental Greece, but also for human occupation *per se* (2) it is a largely aseismic region (Lykousis 2009) and, generally, it lacks major/widespread evidence of submarine failures/instabilities (*e.g.* Piper and Perissoratis 2003) (3) it has relatively shallow water depths (4) geoarchaeological research has already been carried out in various islands of the region, and, even if it involved projects that dealt with the later prehistory, significant knowledge and experience has already been collected (see for example Sampson 2006).

In the last few decades, new research on the Aegean islands has yielded some important contributions to our understanding of human occupation in this region, and, to a large extent, this new data is already in position of addressing crucial questions regarding early human maritime activity and crossings (for a review see Broodbank 2006; Sampson 2006). Instructive examples of a geoarchaeological study can be drawn from the relatively well-attested Middle Palaeolithic evidence from the Sporades (Panagopoulou *et al.* 2001), whereas the finds from Milos, although still inconclusively studied and without a securely datable context, do show the potential for further explorations in the central Aegean (Chelidonio 2001). Artefacts made on quartz and quartzite, including handaxes and cleavers, have recently been reported from Crete: whilst the geoarchaeological study of the associated contexts is still ongoing, a significant number of the finds has been attributed to the Lower Palaeolithic on the basis of typo-technological traits and the preliminary analysis of the geomorphological contexts (Strasser *et al.* 2010). Considering that, according to current knowledge, Crete has been an insular land for most (if not all) of the Pleistocene, a confirmation of the suspected Palaeolithic age of the finds would be a scientific discovery of prodigious significance, especially if the finds prove to date to a period before the appearance of anatomically modern humans. As shown in Fig. 6.18 of the Aegean palaeogeography (Lykousis 2009), before MIS 8, and most notably during and before MIS 10-12 (and for an unknown time-span up to some point in the Early Pleistocene), access to Crete would have been possi-

ble, at least during time-windows of lowered sea-level, through two main routes: from the western side, by way of the emerged terrestrial platforms which would have connected the southeastern end of Peloponnesus with Kithira and Antikithira; from the eastern side, by 'island hopping' through Rhodes and the adjoined islands of Karpathos-Kassos. The western route would have entailed a sea crossing of less than a nautical mile, which is a distance that does not require the employment of any sophisticated watercraft (the simplest raft or even a natural mat would suffice), whilst it falls well within the documented swimming abilities of most mammals. Consequently, although a tentative *seagoing* across small distances can be credibly assumed for both aforementioned routes, adept *seafaring* needs not be invoked, unless further refinement of the Aegean palaeogeography shows that the marine crossings involved significantly larger distances; or, unless other lines of evidence are able to demonstrate a direct link with the coastal areas of Africa or the Near East. In light of the evidence from Flores (Morwood *et al.* 1998), a modest sea-crossing capacity can indeed be envisaged for hominins as early as the Early Pleistocene, but the Cretan evidence cannot yet neither confirm nor falsify such a scenario for the Mediterranean Basin. Although the artificial character of the specimens appears to be beyond doubt (Strasser *et al.* 2010; personal observation of a sample of the material in 2008), the mechanical properties of the raw material (*i.e.* a bad knapping quality) pose immense difficulties when assessing patterned human action or -even worse- reduction strategies and technological attributes; and this is an extra perplexity that researchers need to resolve, particularly with regard to cases where there is overlap in the use of the Cretan sites in the Palaeolithic and the Mesolithic, since quartz is the dominant raw material used in the latter period, too. Nonetheless, what needs to be further investigated and most convincingly established is the age of the depositional contexts with which the implements are inferred to be associated. The contexts of the Palaeolithic finds are Bt horizons of paleosols, beach conglomerates of marine terraces and debris flow fans; on the basis of the Maturity Stages of the paleosols and age estimates extrapolated from radiometric dates on the lowest Pleistocene marine terraces, an age of *ca.* 130-190 ka is suggested as a *terminus ante quem* for the Palaeolithic artefacts,

although the researchers do stress that "these are rough approximations" (Strasser *et al.* 2010, 186). In short, provided that a Pleistocene age is confirmed, the Cretan material illustrates the high potential of Aegean insular sites for yielding important contributions to the unraveling of early human sea-crossing capabilities and -in extent- cognitive abilities, maritime adaptations, and exploitation of marine resources (*e.g.* see discussions in Broodbank 2006; Stringer *et al.* 2008; Joordens *et al.* 2009). Middle and Lower Palaeolithic surface finds have been reported recently from Gavdos, a small island situated 21 nautical miles off the southwestern coast of Crete (Kopaka and Matzanas 2009). Their attribution to such an early age is essentially based on typological/technological characteristics and the degree of surface weathering and patination (*ibid.*). The two implements that are shown in the publication (and reported as of Lower Palaeolithic age), a handaxe and a chopping tool, are made on limestone. Overall, there is no doubt that further research is needed in order to substantiate claims for a Lower Palaeolithic human presence on Gavdos. Last but not least, the Ionian Islands should not be overlooked, as they have already yielded promising results (see above, section 4.4). As part of an extremely active tectonic domain, human habitation on the Ionian Islands (and the preservation of its vestiges) would have been constrained and influenced by a complex tectonic history of emergence and submergence. However, it is likely that for much of the Early and Middle Pleistocene, most of the islands would have been joined to the opposite mainland. The wealth of Palaeolithic finds from mainland Epirus; the relatively well-known Middle Palaeolithic evidence from the Ionian Islands, which includes also artefacts from underwater contexts, and the existing indications for cultural connections with Italian sites, altogether emphasize the encouraging state of research and the potential of this region for yielding Lower Palaeolithic material. Importantly, for the time-spans during which the islands were joined to the mainland, a wide coastal route would emerge, connecting the western parts of Greece with the Albanian and Dalmatian coasts (see Fig. 6.18).

In view of all the above and considering the wider implications of the newly published palaeogeographic maps of the Aegean, what needs to be stressed is that future research in the region needs

not be engaged primarily in underwater investigations, as there are numerous Aegean islands that remain virtually unexplored. When results are being produced by terrestrial surveys, then submarine investigations may follow in the offshore vicinities, if they are deemed both feasible and necessary. An example of such a strategy can be given with regard to paleosols, of which the importance has already been stressed here (chapter 4). The association of Palaeolithic finds with paleosols has been attested not only in continental Greece, but also on Aegean islands (*e.g.* Sporades: Panagopoulou *et al.* 2001; Gavdos: Kopaka and Matzanas 2009⁵⁹; Crete: Strasser *et al.* 2010), and it has already been noted that there may be cases where paleosols recognized on land can be traced offshore by acoustic reflection surveys. All in all, geoarchaeological and geomorphological strategies that have already been (or need to be) applied on continental Greece, with regard to site location models, assessments of site/assemblage formation, and ultimately interpretation, can also be employed in research on insular and/or coastal locations, modified according to the constraints imposed by the latter landscapes. From a large-scale geomorphological perspective, we can divide the Aegean into two basic landscape categories: firstly the basins, which serve as ‘sink areas’ ultimately receiving sediments and material remains; secondly, positive features (ridges, horsts, etc) that essentially serve as ‘source areas’ from which geo/archaeological material is transported into the basins. The land masses that occur today as islands in the Aegean belong to this latter group: they are the topographic highs which would have always been above the level of the sea, the ‘suppliers’ of the now-subsided and submerged depressions. As such, they carry much less potential for preserving material, in comparison to the topographic lows of basinal features. Yet, from a finer-scale perspective and by zooming into the physiography of each one of the islands, similar (albeit of smaller-scale) depressions can be identified *on the islands* as well. Consequently, these should be the starting

points of any future Lower Palaeolithic investigations in the Aegean domain.

Similarly, localities that have so far yielded palaeontological finds can also serve as points of reference for contextual geoarchaeological assessments, let alone that earlier appraisals of the uncovered assemblages may need to be reconsidered, because at the time of their discovery the palaeogeography of the Aegean was less understood. Together with any possible future improvements in the existing chronological schemes, the acknowledgment of extensive land-bridges between Aegean islands and continental Greece and between the latter with Asia Minor will advance our understanding of issues such as the degree of insular endemism and the presence of unbalanced faunas in many Aegean islands (*e.g.* Dermitzakis and Sondaar 1978). Faunal structure, diversity, migration and dispersal, as well as biogeographical distribution, all depend largely on changes of the physical environment and all are highly relevant to human dispersal and colonization (*e.g.* Koufos *et al.* 2005; Spassov 2002). In that sense, it might be of crucial importance whether the Early and Middle Pleistocene configuration of the Aegean region served more as corridor and/or filter, rather than a sweepstake or pendel route, especially for east-west directed hominin migration/dispersal events and faunal expansions (*cf.* Dermitzakis and Sondaar 1978; Kostopoulos *et al.* 2002; 2007).

A final note on issues of depositional contexts

For the time-period that much of the Aegean was an emerged, terrestrial landscape, we can assume that the now-submerged archaeological material was initially (*i.e.* upon discard) subjected to the same main processes (geomorphological, sedimentological, taphonomic, etc) that apply to continental areas. It follows that alluvial and fluvial sedimentation would have been the prime processes for the potential transportation, burial and preservation (or, instead: erosion and reworking) of human remains and artefacts accumulating on the emerged palaeo-surfaces. In fact, during times of subaerial exposure, sediment river discharge in the Aegean would have been appreciably higher than today’s values, especially in adjacent depressions and lakes, close to the regions where prominent rivers debouche large quantities of

59. The researchers note the association of lithic finds with “zones of red soils/*terra rossa*”; my personal observations on Gavdos (2008) can confirm that those “red soils” are paleosols of potentially great maturity.

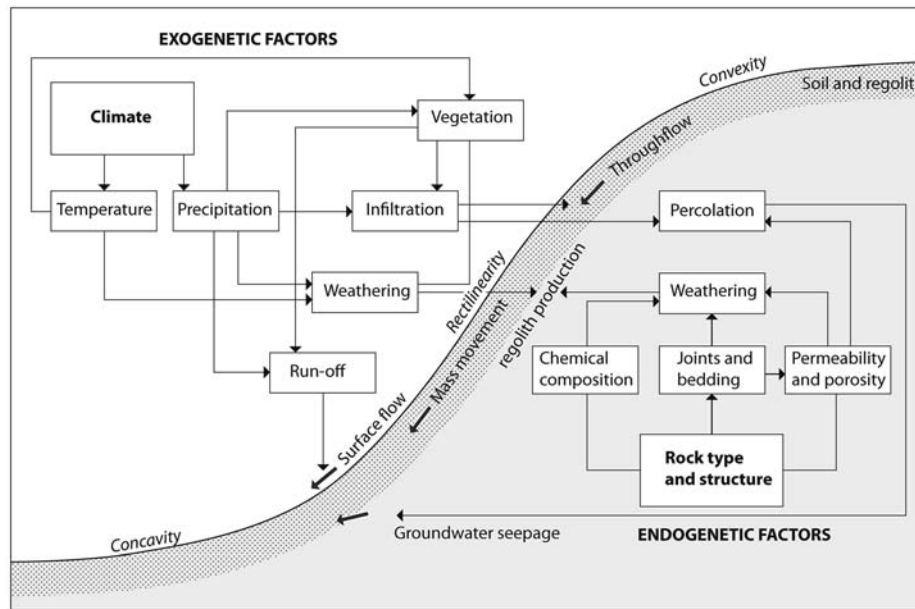


Fig. 6.20 Simplified flow-chart of the slope system with a convex-rectilinear-concave slope as an example. After Clark and Small 1982: fig. 1.1

terrestrial sediments (Lykousis 2009; Stanley and Perissoratis 1977).

A major conclusion that has already been drawn after the examination of the extant Greek Lower Palaeolithic (continental) evidence is that the archaeological record essentially involves findspots associated with secondary contexts. Considering how dynamic the Greek landscapes have been and continue to be, secondary contexts should be expected to dominate the Pleistocene archaeological archive in the future. The now-emerging onshore and -most prominently- off-shore Aegean geoarchaeological record will most likely follow this inconvenient trend. Far from being a pessimistic view, dealing with reworked material from low resolution data-sets does not render it useless, as long as solid and coherent approaches can be developed. For instance, with regard to the Lower Palaeolithic record of the English Channel and the North Sea, Hosfield (2007) exemplified possible methodological means and conceptual frameworks that have already been applied in the terrestrial records; with the appropriate adaptations, such analytical tools can also be fruitfully employed in the maritime realm.

6.5 SURFACE PROCESSES

6.5.1 Introduction

In any kind of environments, the archaeological record has been shaped by the interaction and cumulative effects of syn- and post-depositional taphonomic processes induced by cultural and non-cultural agents (Kirkby and Kirkby 1976; Butzer 1982; Schiffer 1987; Nash and Petraglia 1987; Waters and Kuehn 1992; Ward and Larcombe 2003; Fanning *et al.* 2009).

Here, we focus mostly on the role of the natural processes and specifically those that are designated as *slope* or *surface processes*. Exactly because these operate on land surfaces, namely at the interface of the atmosphere with the lithosphere, their mechanisms and their impact on the geoarchaeological resources integrate and transect elements, systems and structures that belong to interconnected domains of the biosphere: climate, tectonic forces, geological formations and topography (Fig. 6.20). Thus, whilst an emphasis is given on the latter realm (topography), this chapter builds upon the previous discussions on climatic, tectonic and sea-level controls, in order to explore aspects of Quaternary landscape evolution that are likely to have biased the preservation and visibility of the Lower Palaeolithic record in Greece.

In Mediterranean environments, erosion and land degradation have long been considered as significant driving factors in landscape evolution (Inbar 1992; Conacher and Sala 1998; Vandekerckhove *et al.* 2000; Geeson *et al.* 2002; Butzer 2005; Thornes 2009; Wainwright 2009). Grove and Rackham (2001, 8-17) convincingly disprove a long-lasting notion of the Mediterranean as a 'ruined' and 'degraded' landscape, which has suffered extensively from human misuse. However, pointing out the problems of the 'degradationist theory' or the confusion related to the terms 'desertification' and 'degradation', does not mean that the authors deny the importance of erosion: rather than presenting evidence to show that erosion "does not matter", their goal is to "demonstrate that it is not simple" (ibid, 267). Importantly, they also note (ibid, 246): "It is a common fallacy that all erosion represents the loss of soil [...] Sheet, wind and rill erosion, working from the top downwards, do indeed remove soil, but that is not true of the other kinds. With gullying, sidecutting, marine and karst erosion, most of the sediment removed is not soil". As such a discussion falls outside the scope of this section, for the definitions of these terms and the related debate the reader is referred to the abovementioned work, as well as to Imeson 1986; Romero Diaz *et al.* 1992; Conacher and Sala 1998; Thornes 2002; Bloom 2002; Aksoy and Kavvas 2005; de Vente *et al.* 2008. From an archaeological perspective, what matters is that erosion is inherently related to sediment transport, and that desertification and land degradation promote the erosion of both soils and sediments (hence also the disturbance, reworking or destruction of archaeological material). Under this perspective and in line with numerous researchers, who, although acknowledge the limited use of soil erosion *sensu stricto*, they still discuss erosion in its broadest meaning (e.g. de Vente *et al.* 2008), erosion is meant here to include all major eroding processes and agents that operate in slope denudation and landform development (e.g. Della Seta *et al.* 2009; Verheijen *et al.* 2009).

6.5.2 Erosion measurement and modeling

Studies of landscape evolution and/or erosion apply surface process models in two broad theoretical and methodological frameworks: *slope processes*, usually expressed by short-range hillslope transport using the

diffusion equation (e.g. Martin and Church 1997; Jimenez-Hornero *et al.* 2005) and *fluvial processes* (e.g. Montgomery and Dietrich 1992; Coulthard *et al.* 2005; Aksoy and Kavvas 2005; Brown *et al.* 2009), both of which are viewed within the overarching setting of a drainage network⁶⁰ (e.g. Horton 1945; Codilean *et al.* 2006). Factors that need to be parameterized when modeling erosion include lithological properties, soil characteristics, climatic variables, topographic factors (surface roughness, elevation, mean relief, slope angle/length/aspect), runoff attributes, vegetation cover and land use (de Vente and Poesen 2005). Erosion, notably soil erosion, can be measured in four main ways, each of which is commonly associated to a particular spatial scale: (1) change in weight (point scale, 1 m²) (2) change in surface elevation (hillslope scale, <500 m²) (3) change in channel cross section (field scale, <1 ha) (4) sediment collection from erosion plots and watersheds (plot scale, <100 m² and small watershed scale <50 ha) (Stroosnijder 2005). For larger spatial and temporal scales, catchment-wide erosion can be estimated from the transport of fluvial sediment and its deposition in reservoirs; in this case, erosion is inferred from measurements of sediment yield (e.g. Langbein and Schumm 1958; Brown *et al.* 2009). The latter may not be an accurate measure and it most likely underestimates slope erosion mainly because sediment travels intermittently and may be stored in traps within the fluvial system for unknown time-spans (Grove and Rackham 2001; Bloom 2002); moreover, extremely episodic sediment delivery due to catastrophic erosional events will almost certainly be underestimated and/or overlooked during the measuring period (Kirchner *et al.* 2001). Finally, erosion can also be expressed as rates of slope retreat and/or as denudation rates, which estimate the depth of rock/sediment removed from an area in a specified time interval (Bloom 2002). Recently, the use of isotope geochemistry and specifically the application of techniques based on cosmogenic nuclides have revolutionized erosion assessments for

60. Considering drainage basins as three-dimensional land-surface entities, one is forced to identify a continuum rather than a sharp distinction between 'slope' and 'stream' processes (Conacher and Dalrymple 1977). Hence the difficulty in discussing here those processes separately.

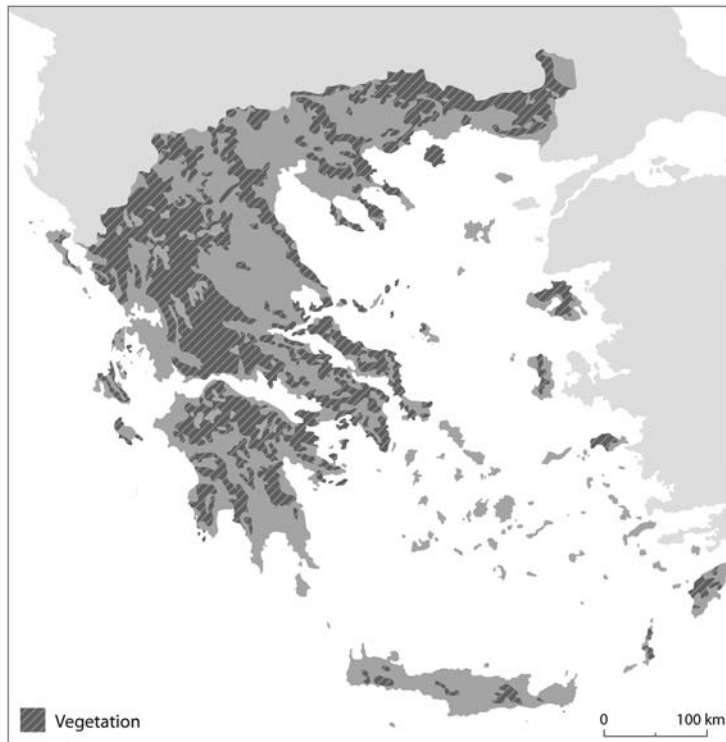


Fig. 6.21 Vegetation cover map of Greece. Shaded areas represent forest, shrubs and vegetated pastures; the remaining areas are cultivated and bare lands. After Kosmas *et al.* 1998a: fig. 5.5 (based on the forest map of Greece, Greek Forest Service)

large temporal and spatial scales (e.g. Schaller *et al.* 2001; von Blanckenburg 2005). Nevertheless, erosion studies that span 10^3 - 10^6 yr⁻¹ time-scales at equivalent spatial scales (e.g. 10^1 - 10^6 km²) are overall scarce due to many reasons, if not because they are bounded to be employed within broader frameworks that address long-term landscape evolution with sophisticated conceptual and numerical modeling (see Mather *et al.* 2002 and Balco and Stone 2005 as examples of notable exceptions; and Bishop 2007 for a recent review).

Problems with investigating erosion and deducing widely applicable generalizations from erosion studies -and especially in Mediterranean landscapes- largely arise due to: (1) the complexity of the interplay between the controlling processes and the non-linear character of their behavior, (2) the heterogeneity of landscape forms (e.g. runoff surfaces) and land-use histories (3) the difficulty in the parameterization and modeling of the involved processes, and the problems of scale (de Vente and Poesen 2005; Thornes 2009). The latter issue, namely the intricacies related to the different spatial and temporal scales used when recording, modeling and extrapolating data on erosion, has acquired a great impor-

tance and has been addressed repeatedly by various scholars (Phillips 1995; Imeson and Lavee 1998; de Vente and Poesen 2005; Stroosnijder 2005; Heimsath and Ehlers 2005; Codilean *et al.* 2006). Most models, be they conceptual, empirical, or physically-based, have limited applicability outside the range of conditions for which they were developed, and many authors argue that erosion rates measured at one scale cannot be regarded as representatives at another scale level (e.g. de Vente and Poesen 2005). Whilst third generation erosion models come to provide valuable solutions to such drawbacks by combining deterministic mechanics and stochastic equations (e.g. Sidorchuk 2009), other recent studies show that it is *possible* to extrapolate current erosion measurements over longer time-scales (e.g. see Peeters *et al.* 2008). For instance, Phillips (2003) explores the reasons behind the fact that a significant number of studies show general consistency or overlap between shorter-term (*i.e.* modern, or Holocene) and longer-term (Quaternary, 10^5 time-frame) rates of erosion, denudation or fluvial sediment yield.

Largely due to their threshold-dominated nature (Schumm 1979; Vanderkerckhove *et al.* 2000; Bloom 2002), geomorphic systems are typically

Formations	Frequency of landslides (A)	Area (B)	Ratio (A) / (B)	Relative frequency of landslides
Quaternary	16.229	15.87	1.022	0.104
Tertiary	30.212	24.00	1.258	0.128
Flysch	35.581	8.48	4.196	0.428
Transition zone to flysch, cherts, schist-cherts etc	2.996	1.22	2.456	0.250
Limestone	3.621	19.50	0.186	0.019
Phyllites-Schists	8.614	18.35	0.469	0.048
Volcanic rocks	2.746	12.58	0.218	0.022
Total	99.999	100.00	9.805	0.999

Table 6.3 Frequency distribution of landslides in different lithological formations of Greece. After Koukis and Ziourkas 1991: Table 21

non-linear, exhibiting complex behaviors that include dynamical instability and deterministic chaos (Thornes 1985; Phillips 1993). Under such conditions, small and short-lived disturbances may have disproportionately large and long-lived effects, thereby inhibiting predictability of future -and reconstruction of previous- geomorphic responses (Phillips 2006). However, as Phillips puts it, “geomorphic systems are evolutionary in the sense of being path dependent and historically and geographically contingent”; in that sense, they are “governed by a combination of ‘global’ laws, generalizations and relationships that are largely (if not wholly) independent of time and place, and ‘local’ place- and/or time-contingent factors” (ibid, 739-740). It is in this respect that the following sections discuss the main aspects of past and present erosional processes, which have contributed in landscape development.

6.5.3 Vegetation

The main relationships between vegetation cover/type, climatic variables (*e.g.* precipitation) and erosion were outlined in section 6.2. Here, suffice it to recall that accelerated erosion dominates in sloping landforms when vegetation cover falls below a value of 40% or even 70% (Macklin *et al.* 1995; Kosmas *et al.* 2000). Nowadays, under interglacial conditions (and largely reflecting anthropogenic interference), about 50% of Greece is bare or cultivated land; total forest area covers about 20% of the land, whereas the rest is covered by shrubs, phrygana and other kinds of maquis vegetation (Fig. 6.21; Kosmas *et al.* 1998a). As discussed earlier, major contractions of tree populations were not restricted only to glacial

maxima but occurred also during shorter (and relatively milder) glacial intervals and cold spells, even within interglacial complexes (Tzedakis *et al.* 2006). Reduced and highly seasonal precipitation, disappearance of woodlands and prevalence of open vegetation with herb and steppic taxa of low biomass would have promoted soil erosivity and runoff (Macklin *et al.* 1995; Leeder *et al.* 1998; Roucoux *et al.* 2008, 1392; but see also Rogers and Schumm 1991, and section 6.2).

6.5.4 Lithology

Different rock types will present different erodibility attributes according to, for instance, chemical composition, joint spacing, porosity and permeability (Clark and Small 1982). Yet, slope development is controlled by many other variables capable of masking or outweighing the lithological constraints, so that it is unrealistic to expect that a particular rock type will consistently produce a specific slope-form or erosional behavior (ibid). Nevertheless, a few simple and broad generalizations can still be made. For example, massive, coherent rocks will erode less rapidly than weak, incoherent rocks; the former will tend to produce free faces in a slope, whilst the latter will likely form more rounded, convex-concave slope elements (Clark and Small 1982). Generally, in the case of ‘hard rocks’ chemical weathering is needed in order to break down the rock to erodible soil or saprolite; whereas with ‘soft rocks’ mechanical weathering and/or direct erosion by runoff or gravity prevails, without the necessity of soil formation for erosion, even if a soil will most likely be present none the less (Leeder *et al.* 1998). An inspection

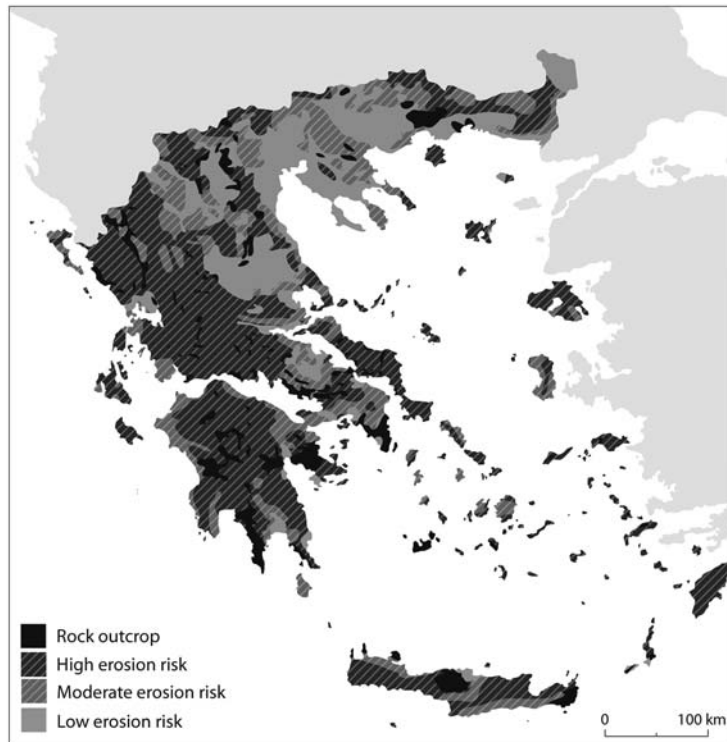


Fig. 6.22 Potential soil erosion risk map of Greece. Modified after Conacher and Sala 1998: fig. 12.3

of the engineering geological map of Greece reveals that the bulk of Quaternary sediments are classified as ‘loose’, with ‘Quaternary cohesive’ rocks being a minority. An indication of the erodibility of the superficial, loose Quaternary deposits comes from the frequency distribution of the various types of slope failures in Greece: after rotational slides (slumps) which affect mainly Neogene argillaceous formations, the next most frequent types of movement, namely earthflows and creep, involve Quaternary sediments (Koukis and Ziourgas 1991). Furthermore, statistical investigation of landslide occurrences in different lithological formations demonstrates that Quaternary sediments have the highest frequency distribution after flysch, a transition zone to flysch, and Neogene sediments (Table 6.3; Koukis and Ziourkas 1991).

6.5.5 Soils

Soils on the uplands and mountainous areas of Greece are poor, shallow and deeply eroded, mainly due to the presence of steep slopes and because of the scarcity and/or destruction of natural vegetation cover; in contrast, soils are deeper, better structured and more productive in lowlands (Kosmas *et al.*

1998a). Soil depth has a great effect on vegetation cover and performance, and it increases with humidity (Kosmas *et al.* 2000). The erosion of soil volume capable of supporting vegetative cover is one of the main causes of land degradation in Greece (Fig. 6.22; Conacher and Sala 1998). Decline of soil structure, loss of organic matter and reduction in aggregate stability and salinization are the key agents of soil degradation, which in turn increases the susceptibility to erosion (*ibid*). Soils formed on hilly Tertiary and Quaternary consolidated landforms typically have a restricted soil depth and limited subsurface layers, such as petrocalcic horizons, gravely and stony layers or bedrock (Kosmas *et al.* 1999b, 27). Extensively degraded areas with skeletal soils are primarily restricted to limestone and secondarily to acid igneous and metamorphic rocks (Conacher and Sala 1998). Particularly limestone formations, which are rather extensive in Greece, produce shallow soils with a relatively dry moisture regime and slow vegetation recovery that makes them highly erodible (Kosmas *et al.* 2000).

When the texture of the parent material is silty and mostly structureless, as with marls, or when the developed soils are thin, as on limestone, then once the

topsoil, rich in organic material and well-structured, is removed, the exposed substrate typically becomes subjected to high erodibility in sloping areas, unless mature, strong and cohesive horizons are present (Bk/Bca or K calcic/calcrete horizons). The upper A and E horizons are both unconsolidated and thus it is not surprising that in most of the buried and/or relict Pleistocene paleosols in Greece these horizons are absent: usually, the assumption is that they have been either stripped off by erosion in the past or removed by farming; in some cases, it can be hypothesized that surface lithic artefacts derive from those fragile, now-vanished horizons, or from the erosion-resistant and preserved B and C or K profiles (Pope and van Andel 1984; Demitrack 1986; van Andel *et al.* 1990; van Andel 1998; Karkanas 2002; Runnels and van Andel 2003). For example, the characteristic autochthonous (residual) red soils of Greece (primary *terra rossa*: van Andel 1998) commonly formed on limestones and other calcareous formations, only rarely present a complete Rhodoxeralf profile and in most cases it is merely remnants of their Bt and/or Bk horizons that are preserved (Yassoglou *et al.* 1997). In contrast, allochthonous red soils (van Andel's redeposited *terra rossa*), much of which are of Tertiary or Quaternary age, are more abundant, exactly because they have formed on lowland, gently sloping or flat landforms, such as lacustrine sediments, alluvial deposits and palaeo-floodplains (*ibid.*). This latter category of *terra rossa* is in itself an indication of past erosion, because the parent materials of those soils have been transported from (mainly) limestone slopes to lower sink-areas (Yassoglou *et al.* 1997). In agreement with previous researchers cited above, my personal observations during fieldwork in Thessaly, Epirus, Macedonia, Peloponnesus and Zakynthos confirm the conclusion that Pleistocene paleosols are almost always to be found best preserved and commonly buried on landforms of low elevations and low gradients (*e.g.* valley bottoms, coastal plains). On upland and high-relief regions, these soils are very rare and are found as eroded, typically truncated remnants; they are preserved only in topographic depressions and/or stable landforms such as plateaus. Soil formation typically requires time-spans of hundreds to thousands of years, and soil development can only be attained in relatively stable landscapes that are neither rapidly aggrading nor eroding (Retallack 2001). Consequently, the relatively thin, spa-

tially discontinuous and patchy, and always truncated Pleistocene paleosols of Greece either indicate relatively short time-windows (in the geological time-scale) of geomorphic stability, or alternatively, they point to past erosional events affecting the most fragile soil horizons.

6.5.6 Land use

The effects of anthropogenic landscape modifications and land use in the biography of erosion and landscape development have long been a primary focus in geoarchaeological, geomorphological and ecosystem management studies in the Mediterranean and in Greece, which is still well-known as a region with a long history of human land use and abuse (van Andel *et al.* 1986, 1990; Runnels 1995; Kosmas *et al.* 1999; Allen 2001; Butzer 2005; Thornes 2009). The long-lasting debate over the human *vs.* climatic impact as major drivers of alluviation and soil erosion during post-glacial times was mentioned briefly earlier and has been thoroughly reviewed and discussed by Bintliff (1992, 2002, 2005), van Andel *et al.* (1990a) and Zangger (1992). Van Andel and Zangger (1990) evaluated a number of geoarchaeological indications from three major projects (in Southern Argolid, Argive Plain and Larissa Basin); they concluded that all three case studies point to landscape instability due to -and after- the spread of farming populations and the onset of woodland clearances, resulting in extensive slope erosion and valley aggradation. Zangger (1992) stressed the time-transgressive nature of this human-induced landscape instability, showing also that such disturbances differ from region to region according to physiographic characteristics and settlement history. All the same, most of these studies entail some recurrent themes with respect to both causal factors and resultant effects. For example, triggering parameters and processes inferred include mainly a combination of the following: the expansion of farming settlements; forest clearance; intensive cultivation and/or over-exploitation of fertile soils; pastoralism and related vegetation disturbance by animal husbandry (grazing, etc); inadequate soil conservation and ineffective or total abandonment of terrace maintenance and gully check-dams; economic and demographic circumstances and policies (Pope and van Andel 1984; van Andel *et al.* 1986; van Andel and Zangger 1990; van Andel *et al.* 1990a; Zangger 1992). Ero-

sion and destabilization or, alternatively, stability, is inferred from geomorphological, sedimentological and pedological indications from the depositional archives, generally encompassing evidence and conclusions such as: soils indicate periods of stability (e.g. Pope and van Andel 1984); erosion events are envisaged as catastrophic sheet erosion on slopes (e.g. van Andel *et al.* 1986); gully erosion stripped off soils, which were then deposited in valley bottoms as stream-flood deposits, whilst debris flows have also been feeding many of the Holocene alluvia (Fig. 6.23; van Andel *et al.* 1990a); shifts to instability, signaled either by mass movements (e.g. debris flows) or channel aggradation, can be abrupt (Pope and van Andel 1984); the degradation of vegetation by cultural or natural processes (or both) is a general prerequisite in all explanatory schemes (e.g. van Andel *et al.* 1990a; James *et al.* 1994; Lespez 2003).

Another recurrent feature in studies of the relation between land use and erosion is the apprehension of the importance of *slope gradient*. For example, neglect or abandonment of terraces on steep slopes is often thought to have been followed by erosion and downslope sediment redistribution, which in cases results in different artefact densities between steep and gentle slopes (e.g. James *et al.* 1994; French and Whitelaw 1999). As expected, slope inclination becomes more significant mainly on upper and middle reaches of the hillslope-channel system (evidenced as e.g. debris flows and streamflood deposits in alluvial/colluvial units), whilst it may be less effective in the lower valleys and coastal plains where flooding predominates during erosional episodes (evidenced as e.g. overbank loams in floodplain deposits) (van Andel *et al.* 1990a; Harvey 2001). Investigating the implications of polycyclic (prehistoric and historic) terracing in Kythera Island, Krahtopoulou and Frederick report that terrain above the 12°-gradient is preferentially terraced (2008, 559). Moreover, they document that after terrace abandonment, the main types of erosion are sheet wash and gully erosion, the latter affecting mainly unconsolidated formations on steep topographies, occasionally causing almost complete denudation of the slope, which in turn produces significant sediment flux to the local fluvial system. Similarly, an investigation of contemporary erosion on terraced lands showed that sediment loss after abandonment of cultivation increases according

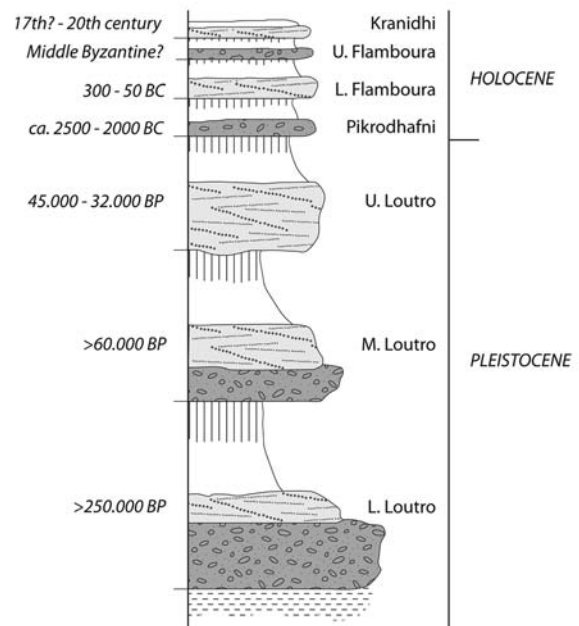


Fig. 6.23 Quaternary alluvial sequence from southern Argolid (Peloponnese). Cobbles with a chaotic structure indicate debris flows, whilst stratified gravels are streamflood deposits; blank zones are overbank loams and vertical lines denote soil profiles. Although the dates give only approximate ages, they do highlight an apparent discontinuity in alluviation events. Modified after van Andel *et al.* 1986: fig. 4

to slope gradient, which -in the case of very steep slopes- constitutes the main determinant of erosion irrespective of land use (*i.e.* cultivation, short- or long-time abandonment) (Koulouri and Giourga 2007). Single-storm interrill erosion on cultivated soils formed on slopes of 6% to 24% inclination, on Pliocene and Quaternary alluvia in Thessaly, was found to be influenced by surface crusting, whereas sediment delivery was mainly conditioned by rainfall intensity, rain kinetic energy and runoff amount (Dimoyiannis *et al.* 2006). In another study-area, this time in Northern Greece, high degree of erosion was documented for slopes greater than 6% inclinations (Anthopoulou *et al.* 2006). Soil survey data from Lesbos Island show that slope angle has a variable effect on erosion, depending on annual rainfall: in the semi-arid zone, soils on slopes greater than 12% are severely eroded, whereas under the same slope class, the soils of the sub-humid zone were found to be moderately eroded (Kosmas *et al.* 2000). Fields

with rain-fed cereals (which is a rather widespread land use in Greece) show the largest values of soil loss in the period from early October to late February, when rainfalls are of high intensity and long duration and the soils are almost bare (Kosmas *et al.* 1997). This kind of studies provide direct empirical support to the decisive role of slope gradient and extreme erosional episodes, such as catastrophic storm events (see also Vandekerckhove *et al.* 1998; López-Vermudez *et al.* 1998; Kosmas *et al.* 1999b; Grove and Rackham 2001, 218–311, and Casana 2008 for examples of similar results from other Mediterranean countries).

Although research on Holocene erosion in Greece continues to provide evidence for a strong correlation between erosional episodes and cultural rather than natural processes (*e.g.* Fuchs 2007), there is at the same time a growing awareness of the driving role that climate, tectonics and geology acquire in preconditioning human-induced erosion (*ibid*; Allen 2001; Casana 2008; Thornes 2009). Bintliff (2002) suggests that instead of focusing on climate or anthropogenic causation as monocausal or deterministic alternatives, there is much stronger evidence for viewing geomorphic and environmental parameters as setting up a ‘pre-adaptation scenario’ of a sensitive landscape, where cultural and natural trajectories intersect to create ‘windows of opportunity’ during which extreme erosion events are likely to occur. This viewpoint is best understood when considering Mediterranean landscape evolution as a “punctuated equilibrium rather than a uniformitarian process of prolonged change” (Bintliff 2002, 418). From this perspective we can evaluate the evidence for prolonged times of stability interrupted by erosional events, the latter being rare and brief but extreme enough to have caused large-scale disruptions that are now manifested in depositional sequences as discontinuous alluvia and colluvia (*e.g.* see Fig. 6.23; Pope and van Andel 1984; van Andel *et al.* 1990a; Bintliff 2002; *cf.* chapter 6.2 and see discussion below).

Anthropogenic slope alteration, agricultural practices, land abandonment or change of land use, all may result in contrasting effects for the ability of soils to resist erosion: in some cases such parameters lead to deterioration of soils whilst in others they tend to improve soil stability (see papers in Conacher

and Sala 1998 and in Geeson *et al.* 2002; Grove and Rackham 2001). For example, there is ongoing discussion about the role of terraces in erosion control and whether abandonment of terraced cultivation results in increased erosion or not (Allen 2009). Likewise, terracing affects artefact mobility and site integrity, and terrace construction methods may either impede or improve archaeological preservation and visibility (Krahtopoulou and Frederick 2008). That being said, the general trend is that slope erosion and instability have indeed been accelerated by anthropogenic processes, as the studies mentioned above on prehistoric, historic and contemporary erosion make clear (*cf.* Macklin *et al.* 1995; Wainwright 2009). Dedkov and Moszherin (1992) classified river basins into natural or modified states by using land use type and extent, in an attempt to evaluate the relative importance of natural and human contributions to the sediment yield of mountain river basins across the world. Their results show that present sediment yields (and hence averaged erosion rates) in the Mediterranean have the highest anthropogenic component of any other climatic-vegetation zone, and although the premises of this finding may be questioned, their conclusion is still cited as generally solid (*e.g.* Macklin *et al.* 1995, 16; Thornes *et al.* 2009, 245).

6.5.7 Topography

In simple terms, landscape evolution is geomorphologically expressed mainly by the transfer of mass from source areas to accumulation areas (Cendero and Dramis 1996). In effect, a fundamental contrast in erosional style and magnitude is between flat and steep terrains, with erosion being weaker in the former and stronger in the latter (Stallard 1995; Bloom 2002; Huggett 2003). Thus, physical denudation depends primarily on regional relief and secondarily on runoff and other environmental factors: physical (mechanical) weathering processes, mass wasting and erosion are accelerated by steep relief, especially in areas where orogeny is active (Schumm 1963 cited in Stallard 1995, 20; Bloom 2002, 338), as it is the case for Greece (*e.g.* Reilinger *et al.* 2010). Elaborating further on this assessment, Pinet and Souriau (1988) divide river basins that drain in young orogenies into two parts: below 600 m there is a region of uniform sedimentation, residing in subsiding fore-

land basins, whereas above 600 m lies a region of erosion. Mountainous regions erode at rates of at least 10 to 100 cm/1000 yr, an order of magnitude more rapid, regardless of climate, than lowlands with typical rates of 1 to 10 cm/1000 yr (Bloom 2002, 338). In other words, denudation rates are generally positively correlated with both altitude and relief: erosion is promoted by greater elevation and steep relief, and deposition is advanced in lower altitudes and on gentle/low relief (Bloom 2002; Phillips 2005; Wainwright 2009).

It is thus not surprising that in many large-scale studies that link tectonics and surface processes, hillslope erosion is modeled *as a function of either elevation or slope* (Montgomery and Brandon 2002 and references therein; Bishop 2007). Ahnert (1970) reported a linear relation between erosion rate and mean local relief for mid-latitude drainage basins. Montgomery and Brandon show that Ahnert's linear correlation holds well "in tectonically inactive low-erosion-rate landscapes, but provides only a lower limit for erosion rates in tectonically active landscapes" (2002, 485). The latter researchers demonstrate the presence of two main types of landscapes in tectonically active settings, with two distinctive geomorphological controls on landscape-scale erosion rates (*ibid*, 487):

1. low-relief, low-gradient landscapes where erosion rates relate linearly to mean slope or local relief; here, climatic or tectonic controls direct erosion rates through changes in hillslope steepness
2. high-relief, high-gradient landscapes: here, changes in tectonically-driven rock uplift rate influence erosion rates through adjustments in the frequency of slope failure (primarily, landslides).

Effectively, for the second type of landscapes, any increase in mean local relief (*e.g.* due to deglaciation of over-deepened valleys) to values approaching the limiting relief, necessitates a substantial increase in erosion rates (Montgomery and Brandon 2002). The study of Korup and colleagues corroborates these conclusions, at the same time emphasizing that the contribution of catastrophic slope failures to total erosion is not restricted to areas of highest relief and/or strong rocks: hillslope and relief adjustment by means of large events (landslides) occur also in tec-

tonically active areas of moderate relief (*e.g.* at 300-700 m asl, along fault-bounded, mountain range fronts), and include also soft rocks, usually where "discontinuities and low rock-mass strength control slope stability, whether or not threshold slopes have developed" (2007, 589).

Kirchner *et al.* (2001) estimated erosion rates at 10 kyr time-scales in mountainous regions by use of cosmogenic nuclides (^{10}Be), and found a large mismatch when these are compared to conventional sediment yield measurements over years or decades. They interpret this as the result of large, albeit rare and extremely episodic events of sediment flux that are not reflected in the short-term measurements. Importantly, they also demonstrate that the driving factors of episodic erosional events (*e.g.* deluges) must be highly correlated in space (*e.g.* in both large and small catchments). In sum, they conclude that mountainous landscapes exhibit an erosional regime which entails two distinct forms of sediment delivery: incremental erosion, which prevails most of the time but accounts for a small part of the total sediment yield; and catastrophic erosion events that are rare and brief but dominate the long-term erosion rates (Kirchner *et al.* 2001, 593). Further support to the above assessments are given by other studies, which yielded similar qualitative results on the actual and potential destructiveness of such low-frequency large-scale events and the role of landslide phenomena (rock and debris falls and avalanches, debris and earth flows, slides) for landscape evolution in Europe (Cendrero and Dramis 1996). Wainwright, for example, concludes (2009, 190): "It can be argued that major landslides are, at least in the longer term, likely to be the most important landscape-modifying process in the Mediterranean landscape".

6.5.8 Geomorphological opportunities for the preservation of Lower Palaeolithic material: a working hypothesis for the Greek landscapes and the role of topography

As far as relief is concerned, Greece is dominated by mountainous areas with steep slopes (Kosmas *et al.* 1998a). The mountainous parts occupy 64.4% of the country, while lowlands with elevations less than 200 m cover the remaining 34.6%, of which "the real

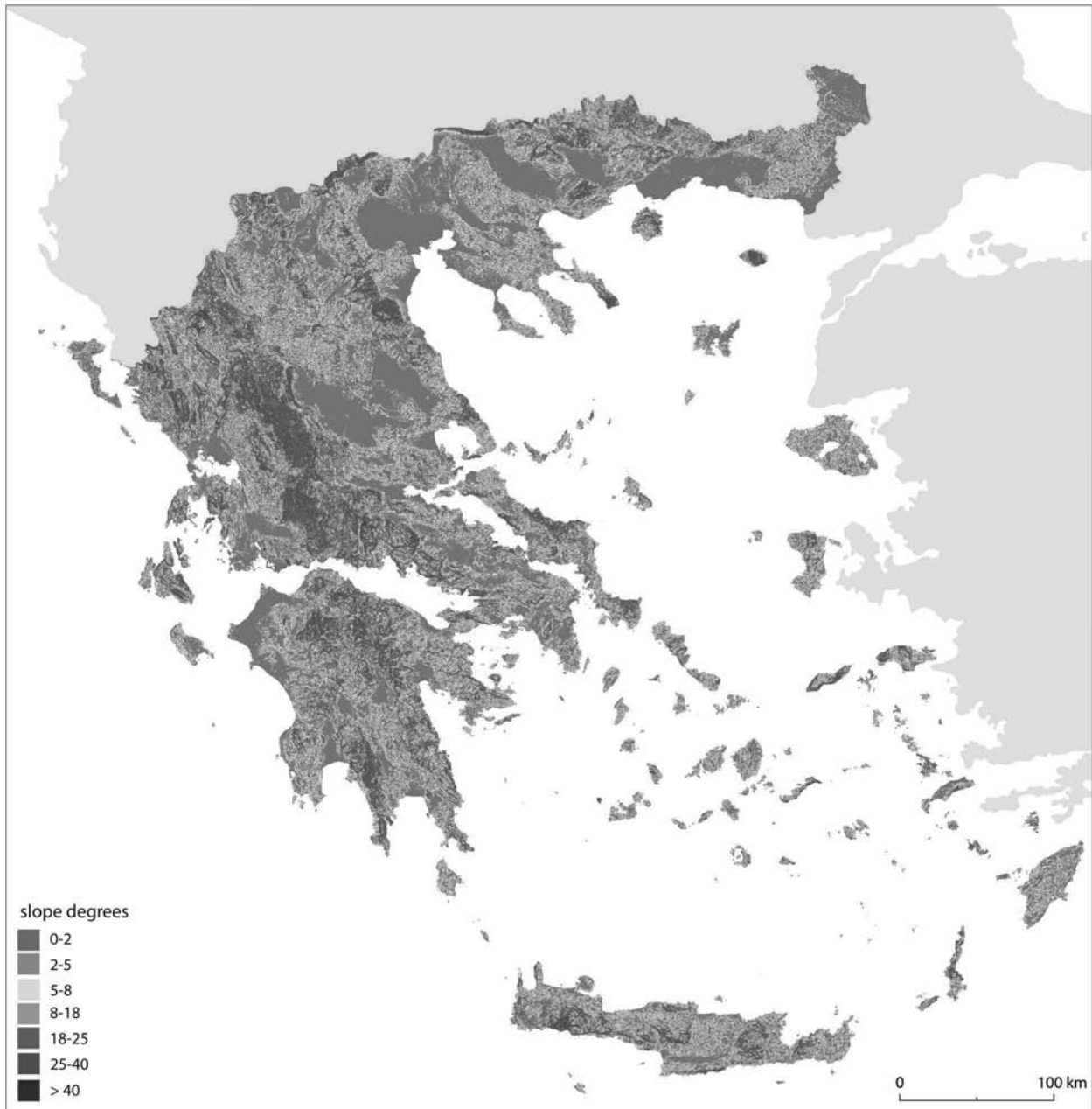


Fig. 6.24 Slope map of Greece. The map was produced in ArchGIS 9.2 and it is based on 1:250,000 topographic maps with a 20-m contour interval

plains reach only 25%” (Koukis and Ziourgas 1991, 48).

As a working hypothesis, I argue here that it is only in this latter 1/4 (or 1/3, at best) part of the country, where Lower Palaeolithic evidence may have survived up to the present in a primary and/or secondary

context. The remaining *ca.* 60-70% of hilly-to-mountainous terrain, with the exception of caves and rock-shelters, will hardly yield any evidence, and if it does, the material will be either context-less, or from a secondary and -most probably- tertiary context. Obviously, the basic argument behind this assessment is that low gradient favors the persistence of deposi-

Slope class	Slope Angle (degrees)	Area (km ²)	% of total land	Geomorphological classification
1	0 – 2	37411.65	28.3	plain to slightly sloping
2	2 – 5	20938.85	15.9	gently inclined
3	5 – 8	16694.50	12.6	strongly inclined
4	8 – 18	34468.60	26.1	strongly inclined to steep
5	18 – 25	14197.23	10.8	steep
6	25 – 40	8069.57	6.1	steep to precipitous
7	> 40	199.61	0.2	precipitous to vertical
Total		131980.01	100.00	

Table 6.4 Numerical attributes of the slope map of Greece

tional landforms, whilst high gradient will be predominated by erosional ones.

Indications that the Greek topography has been and still is unfavorable for the preservation of the geoarchaeological archive were outlined above in relation to vegetation, lithology, soils, topography and land use, whereas the relevant role of climatic, tectonic and sea-level controls have been discussed in the corresponding chapters. Based on the aforementioned relationships between relief/slope and erosion, slope angle is used below as a surrogate for mean local relief and as a proxy for assessing long-term erosion at the landscape-scale, in order to support the argument presented above about the preservation of the Lower Palaeolithic record. In the absence of erosion models at the landscape-scale; and under the premise that “even the limited existing potential for spatial and temporal syntheses should no longer be ignored” (van Andel and Tzedakis 1996), I produced a slope map to use as a morphologic measure for evaluating past and actual biases in archaeological preservation and visibility introduced by erosion (Fig. 6.24). Slope classes, their geomorphological classification and equivalent total spatial extent are given in Table 6.4.

The slope map provides an immediate visual impression of patterns of surface steepness in Greece. Clearly, the areas covered by the first slope class (0°–2°, shown in dark green) mainly represent the sedimentary basins and lowland coastal plains of Greece –the “real plains” of Koukis and Ziourgas (1991), which are also the places where the vast majority of Pleistocene sediments have accumulated (compare Fig. 6.11 with Fig. 6.24). Apart from basins, this slope class (plain to slightly sloping) should also cor-

respond to either smaller-scale, inter- and intramontane topographic depressions, or to plateaus: an example of the former type would be the numerous karst and solution basins of Epirus (dolines, poljes, ‘loutsas’; see section 4.5), whilst the latter are well exemplified by the plateaus of Macedonia. In all of these settings, deposition prevails over erosion, which, in the case of the larger alluvial plains is essentially restricted to lateral fluvial erosion.

The second slope class represents gently inclined slopes and typically shows a clustering mostly at the fringes of the aforementioned basins/depressions, but also occasionally within them. The Middle Thessalian Hills offer a good example of such a gently sloping landscape (Fig. 6.25, B: 1–3). Those fluvio-lacustrine landforms, dividing the Karditsa and Larissa basins, were either uplifted or did not subside during the Early and Middle Pleistocene, when the adjacent basins were subjected to subsidence (Caputo *et al.* 1994; see section 4.6). This divergence in tectonic history largely explains the difference in morphology and erosional history, and hence also archaeological preservation and visibility: whereas the Middle and Early Pleistocene sediments of the Larissa basin lie now in great depths and are covered by later (Late Pleistocene and Holocene) alluvia, their equivalents on the Middle Hills were always subaerially exposed and thus subjected to erosional processes (see 6.3 above for more details); erosion may have been slow and imperceptible, like in the case of soil creep, but it did accelerate in prehistoric and historic times due to human intervention, today reaching values as much as 1.7 cm of soil removal per year, with rill and inter-rill erosion affecting the cultivated slopes (Kosmas *et al.* 1999b; van Andel *et al.* 1990a; Dimoyannis *et al.* 2006). Other types of landforms that would be fairly

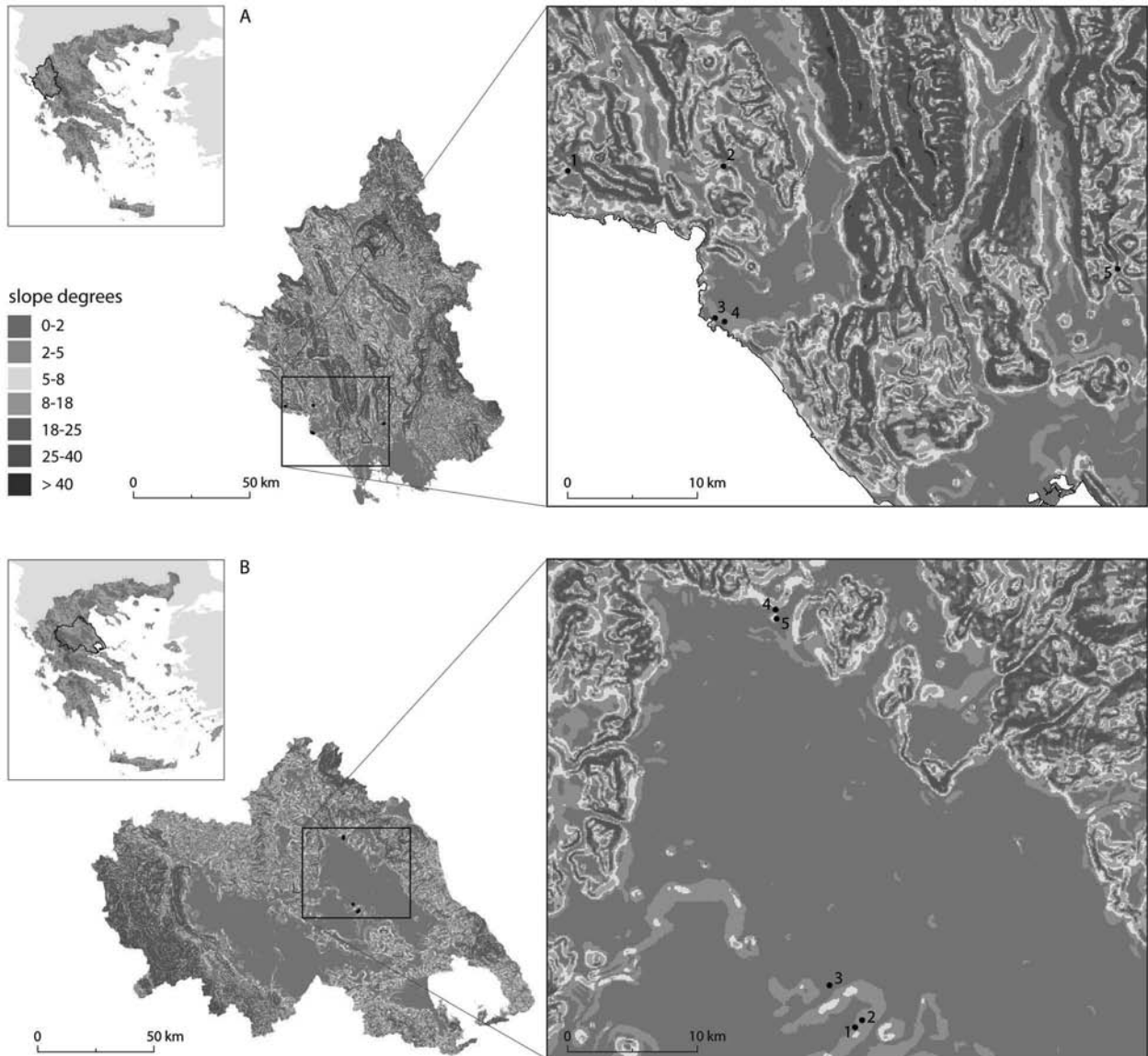


Fig. 6.25 Slope maps of Epirus (A) and Thessaly (B), showing the locations of some archaeological sites and localities with Pleistocene outcrops surveyed by the author and discussed in sections 4.5 and 4.6, respectively. (A): 1) Ayia (see App. I: 28, 29); 2) Morphi (see App. I: 30-32); 3) Ormos Odysseos; 4) Alonaki; 5) Kokkinopilos (most figures in App. I). (B): 1) N. Karyes, outcrop of 'upper Hochterrasse'; 2) N. Karyes, outcrop of 'upper Hochterrasse' in a quarry (see App. II: 6-8); 3) Nikaia, outcrop of 'lower Hochterrasse' (see App. II: 5); 4) Rodia, Kastri Quarry, outcrops of 'upper Hochterrasse' and/or Rodia Formation (see App. II: 10-14) 5) Rodia, site FS 30 (see App. II: 15a)

well-represented by this class involve alluvial and colluvial fans, such as those formed at the fringes of the Thessalian plain (Demitrack 1986), or those of the Argive plain mentioned earlier (Pope and van Andel 1984). Generally, it is exactly because they develop at the interface of a mountainous terrain with a lowland plain or a valley floor that landforms such as

alluvial fans present a dual character with respect to resistance to erosion, persistence in time and preservation.

The rest of the slope classes refer to strongly inclined up to almost vertical slopes, which altogether make up the characteristic rugged landscape of Greece.

This mountainous regime is best exemplified by the Pindus mountain chain, which forms the orogenic backbone of Greece with a NW-SE direction and is easily recognized on the map as a belt of red-hued colours (Fig. 6.25, A). From the perspective of geomorphology, the mountainous realm epitomizes the effects of erosional surface processes, and it can be collectively understood as an assemblage of residual landforms, each in the process of being consumed or transformed by erosion. As mentioned previously, this is the high-gradient relief where erosion rates are regulated by the frequency of slope failure. Indeed, studies of engineering geological conditions in Greece with a particular emphasis on landslide distributions show that unstable zones involve mainly areas with either steep slopes and influences by strong deformation stresses in the past, or areas that are still affected by active geodynamic regimes; Central and Western Greece are in that respect the most sensitive regions (Koukis and Ziourkas 1991; *cf.* chapter 6.3). Particularly, Koukis and Ziourkas (*ibid.*, 54) show that landslide frequency in Greece increases linearly with elevation, whilst the frequency distribution according to relief shows that the majority of landslides (65.6%) appear in areas of intense relief.

Yet, how secure is the assumption that the patterns of surface steepness visualized in the map of Fig. 6.24 can be regarded as ‘representative’ for a time-period that reaches up to the Early Pleistocene? First of all, the initial argument about the topographic control on the preservation of archaeological material is put forth to explore *general trends* dictated by geomorphic conditions, and as such it is not meant to reconstruct palaeotopography, let alone at the hill-slope-scale. Nonetheless, we can safely assume, as a general trend, that the mountain chain of Pindus (to use an example) was a mountainous region of high-relief also during the Pleistocene. Similarly, the sedimentary basins were ‘always’ terrains of low relief during the Pleistocene; in fact, many of them were formed in the Miocene and continued to subside in the Pleistocene: low gradients were in those cases already in place much before the extensional tectonics of the Pleistocene⁶¹ (see section 6.3). In short, at the particular level of generalization used here, if we consider the onset of the Pleistocene as *ab initio* datum for landscape development, then the ‘Pleistocene

landscapes’ inherited a topography in which the Thessalian plain was already a plain and the Pindos mountain range was already in place⁶². Even if we consider that parts of today’s basins were not as flat as they appear now but have been flattened in the course of the Pleistocene; and relief in mountainous regions was not as high as it is now but slopes have gradually steepened (during orogenic development); then, the argument above is further reinforced, because in the former case, sediment accumulation (and hence burial of archaeological material) is required for the ‘flattening’, and erosion/denudation (hence sediment transport and disturbance of archaeological deposits) is assumed for the ‘steepening’ of mountainous relief. The situation of basin inversions, discussed more thoroughly in section 6.3, is in this respect the most notable exception, wherein a relief that used to be of low gradient in the Early Pleistocene (hence including depositional landforms), has been steepened in the course of time and it is now depicted as a strongly inclined and/or steep terrain. Again, the very same processes inferred (uplift, inversion, drainage diversion or rejuvenation, denudation) exhibit an erosional character that does not undermine the validity of the principal assessment.

Apart from this latter case, and besides situations where a once-low-gradient hillslope may have steepened by tectonic activity (*e.g.* due to a fault), all major and widely used models of slope evolution assume a development where high gradients decline into lower values, and not *vice versa*. In the model of *slope decline*, the upper part of the slope erodes faster than the lower segments of the profile, eventually leading to an overall decline of the slope, whilst in the *slope replacement* model, each slope unit retreats until it is replaced by a lower-angle unit

61. In the geological time-scale and time-span considered, localized and/or sporadic occurrences of steep slopes and/or slope segments *within the sedimentary basins* is regarded here negligible.

62. Landscape evolution can only be viewed as a continuum; the employment of a datum (the onset of Pleistocene) for *ab initio* considerations of landscape development is used here only to clarify this specific statement on the inherited palaeotopography.

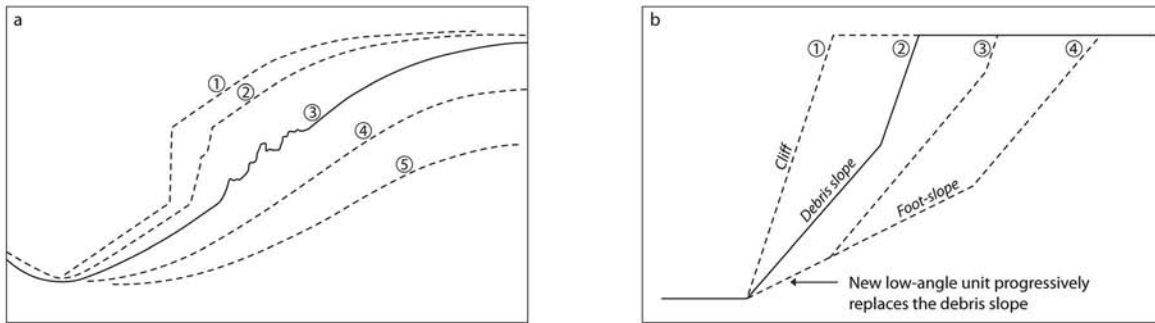


Fig. 6.26 Models of slope retreat. a) slope decline, b) slope replacement. After Clark and Small 1982: fig. 5.11, 5.12

growing up from below⁶³ (Fig. 6.26; Clark and Small 1982, 73).

Therefore, although we cannot evaluate in which stage of their evolution the slopes (*i.e.* basically slope classes 3 to 7) occur at present, we can still consider three main possibilities:

1. According to slope evolution models, whatever the gradient is now, the slopes were even steeper before (*i.e.* in previous stages of their evolution trajectories).
2. Some slopes may have been of lower gradient and at some point were steepened by an erosional episode (*e.g.* a landslide due to a heavy rainstorm, or a collapse due to an earthquake or fault activity); in this case, their denudational character remains, and it is reasonable to assume that archaeological material resting there would have been removed, either during the episode itself or afterwards, during the (erosional) adjustment of the slope towards a new graded profile (*cf.* Kirkby 1971; Montgomery 2001).
3. Some slopes may have retained their (high) gradient unchanged for a long period as:

- a. 'high cohesion slopes', *e.g.* with maximum slope angles within the range of 40°-50° or even higher; but these are typically free of debris, the latter collecting at the slope base as talus.
- b. 'repose slopes': these are also denudational forms, commonly appearing within the range of 30°-35°; they are strongly controlled by the angle of repose of the overlying particles that mantle the slope and are being slowly removed by gravity-controlled processes (Clark and Small 1982). Loose, surface material can indeed remain at the angle of repose for considerable time-spans, but it is unlikely to do so in the time-scale of a complete glacial-interglacial cycle (see argumentation below).

Numerous field data and experimental studies indicate that erosion intensity increases linearly with slope angle until a threshold value; when this value is exceeded the relationship inverses and erosion decreases instead (*e.g.* Liu *et al.* 2001). Because this critical slope gradient (the threshold value) depends on many interrelated factors (*e.g.* grain size, soil bulk density, surface roughness, runoff length, net rain excess, friction coefficient of soil), it differs in the various relationships, but it generally appears in the range of 41.5°-50° (*ibid.* and references therein). However, a decrease in the values of erosional parameters (*e.g.* runoff depth, overland flow velocity, scouring ability of overland flow) or total erosion, does not eliminate the disturbance effects of erosion: to put it simply, erosion rates may be decreased in a slope of >45 degrees as compared to a range of lower angles (*e.g.* 10°-45°), but erosion is definitely there,

63. A third model, that of *parallel slope retreat* "suggests that each of the upper slope units retreats by the same amount so that the whole profile (not just the individual units) retains its form but leaves an extending concave unit (a pediment) at its foot" (Clark and Small 1982, 74). This model, where slope development is essentially controlled by the rate of retreat of the free face, necessitates particularly resistant rocks and is best fitted in landscapes of arid and semi-arid climates. If it should be considered applicable to landforms of hard rocks in, for instance, southern Greece, it still does not affect the validity of the argument.

and capable of eventually removing detritus resting on the slope until a new threshold gradient is attained.

Equally numerous are the studies on clast entrainment and transport by slope and fluvial processes (e.g. Carrigy 1970; Church and Hassan 1992; Poesen *et al.* 1998). Geoarchaeologists and geomorphologists have used basic principles of gravity-induced transport and hydraulic mechanics to investigate the modes in which geomorphic processes affect archaeological material and site formation (Rick 1976; Schick 1987; Wainwright 1992; Fanning and Holdaway 2001; Morton 2004; Hosfield and Chambers 2004; Fanning *et al.* 2009). Overall, the general patterns observed by these two bodies of research seem to accord fairly well, which is expected if we consider artefacts as another type of clast, exhibiting similar mechanical behavior as natural angular material does. Thus, Rick (1976) found that lithic artefact density increases near the bottom of the studied site where slope angle is smaller, and average weight of lithic artefacts increases where slope decreases. The point to be stressed is that artefacts do move down-slope under the influence of erosional processes, if not gravity alone; their transport distances and rates are largely controlled by slope gradient and may or may not vary according to size, shape and weight (Petruglia and Nash 1987; Morton 2004). Fanning and Holdaway cite the work of Poesen, which indicates that “the steeper the gradient, the longer the potential transport distance”, and that “stones resting on very gently sloping surfaces are likely to move only short distances” (2001, 671). The latter scholars demonstrated that inter-rill entrainment does not affect artefacts larger than 2 cm (in maximum dimension) *on gradients less than 5°*, concluding that on such low-gradient surfaces, geomorphic processes like surface wash do not have significant effects on artefact distributions (Fanning and Holdaway 2001, 681). Another important result comes from field experiments and simulations of artefact movement, which show that most of the transport occurs in the period immediately following ‘site abandonment’ (Wainwright 1992).

The nine-unit land-surface erosion model and its geoarchaeological significance

One of the most widely used models of slope form and evolution is the ‘nine-unit land-surface model’ of Dalrymple and colleagues (1968). As French remarks (2003, 30), this model “is probably one of the best ways of envisaging erosion and landscape change...It forces one to visualize what is going on in each part of a landscape *at whatever scale of investigation is being used*” (emphasis added). Moreover, French suggests that the model “gives potential foreknowledge of where there may be good and poor archaeological and palaeoenvironmental preservation of sites and deposits” (ibid, 32). Furthermore, its significance to the exploration presented here lies also in its process-response defined units and the spatial correlation between soil processes, water movements and gravity (*cf.* Conacher and Dalrymple 1977)

Essentially, the model presents an idealized cross-section through one-half of a valley, from watershed (top) to river valley (bottom) (Fig. 6.27). The uppermost unit (1), the interfluvium, is almost flat (0° to 1°) and is characterized by pedogenic processes (soil formation). Unit 2, the seepage slope, has modal slope angles between 2° and 4° and the dominant process is eluviation associated to lateral subsurface water movement. Unit 3 is a convex slope segment that can be regarded as the upper part of the fall face (French 2003, 31), with a gradient of 35°-45° and with creep being the dominant process. The next unit (4), the fall face, is the steepest part of the profile with gradients higher than 45° (and commonly >65°), “characterized by the exposure of the parent material and the general absence of soil and vegetation” (Dalrymple *et al.* 1968, 64); main processes here are rock falls and slides. Unit 5 is the transportation mid-slope segment with 26-35 degrees of slope; this may be the most actively eroding of all units, characterized by movement of material down-slope by flow, slump, slide, creep and surface wash (ibid, 65). Unit 6 is essentially the locus of redeposition of colluvial material derived from higher up the slope profile by mass movement processes or by surface and subsurface water action. Unit 7 is the alluvial toeslope in the floodplain, it usually exhibits 0-4 degrees and is characterized by alluvial deposition; its main difference with Unit 6 is that material here

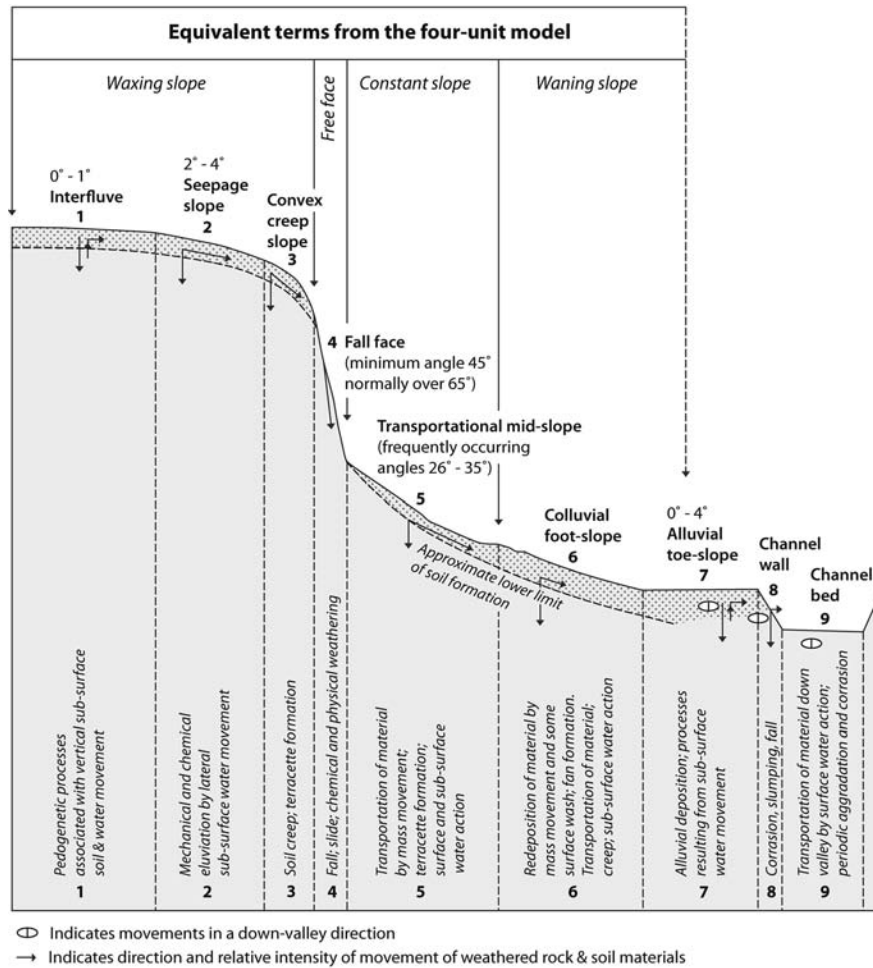


Fig. 6.27 The nine-unit land-surface model of Delrymple *et al.* (1968). Modified after Clark and Small 1982: fig. 5.10

is derived from upvalley rather than from upslope. Finally, Unit 8 is the bank of the river or stream, subjected to stream corrosion and slumping of the channel wall, whilst Unit 9 is the active channel, marked by bed transport down valley, aggradation and erosion. It is important to realize that “in any one land-surface, only unit 1 must occur, it must be first in the profile, and it must occur only once. The remaining eight units may or may not all be present; they may occur in any order; and they may occur more than once” (Dalrymple *et al.* 1968, 73).

What is made immediately clear from the model is that erosion and sediment transport (or, to use a more general term: instability) prevails in units 3, 4, 5 and -needless to say- units 8 and 9. Accumulation and redeposition are the main geomorphic processes operating in units 6 and 7, whereas units 1 and 2 are characterized by neither deposition nor erosion, but

rather, soil formation. Interpreting this in geoarchaeological terms (Table 6.5), one reasonably assumes that:

1. archaeological material is most likely to be found, and is most likely to be in primary context, only in units 1 and 2, namely at a gradient of 0° to 4°, where soil formation may engulf and protect sediments and artefacts. A primary context may be preserved also in unit 7 (the alluvial toeslope, with slope angles again between 0° and 4°) but, due to the dynamic nature of floodplains, a high degree of preservation is adequately advanced only under the combination of specific circumstances, for instance rapid burial associated with sedimentation of alluvial fines, followed by long-term stability and soil formation; if such conditions are not met, water movement and alluviation will most probably result in some sort of

Unit	Slope Angle (degrees)	Geomorphic Process	Potential for Preservation	Archaeological Context	Archaeological Visibility
1, 2	0 – 1	soil formation	high	primary	low, medium?
	2 – 4				high?
7	0 – 4	alluvial sedimentation	medium	?primary? secondary	low, medium
4	45 to >65	slope failure (landslides)	none	none	—
3, 5, 8, 9	26 – 45, possibly even higher	sheet erosion, soil creep, mass movements, channel corrosion, streambed transport	low	secondary, tertiary	high
6	modal angles	redemption of colluvial material by mass movement, surface wash	medium	secondary	low, medium

Table 6.5 Summary of main geoarchaeological conclusions deduced from a hypothetical classification of the landscape according to the nine-unit land-surface model. Assessments on archaeological context and visibility are to some degree of speculative nature and are noted here only as 'most probable possibilities'. Artefact visibility, for example, can be high on lagged surfaces, low on depositional surfaces (because of burial) and somewhere in between (medium) on erosional surfaces. See text for discussion.

disturbance and hence the formation of a secondary context.

- archaeological material is not to be found in unit 4, the 'fall face'.
- archaeological material is least likely to be found in unit 3 (the 'convex creep slope' of 35°-45°), in unit 5 ('transportational mid-slope' of 26°-35°, the most actively eroding) and in units 8 and 9 (channel-wall and -bed, respectively). If there is any material preserved in those units, it will most certainly be from a derived context (secondary or tertiary).
- archaeological material is likely to be found in unit 6 ('colluvial foot-slope'), but it will commonly be in a secondary context, as material coming from upslope. Of course, there is also the possibility that material was discarded on a colluvial foot-slope and was quickly buried by colluvial sediments; hence a primary context cannot be excluded, but it would be rather exceptional.

6.5.9 Discussion and conclusions

The most compelling conclusion of the examination unfolded in this chapter is that the controlling factors behind erosion in Greece, namely the nature and extent of vegetation cover, the lithology of surface materials, the characteristics of the soils, and the effects of a long history of land (mis)use, all are accentuated

by the topographic setting and, essentially, the high relief of the Greek landscape.

Most -if not all- of the lithic scatters found today *on the surface* were probably once buried, unless they are found in very stable, low-relief landforms that were most of the time unaffected by stream and slope processes. Where it can be shown or safely assumed that they were indeed once buried, their exhumation inherently implies an episode of disturbance, the degree of which depends in turn on the processes involved, hence greatly on slope gradient. For instance, on steep slopes, it is difficult to envisage a low-energy winnowing of the finer sediment matrix leaving the artefacts behind as 'lag deposits'. If they were not buried, it is again only in the case of very specific erosion-protected landforms that artefacts can be considered to have escaped disturbance. Artefacts that were once buried on low-gradient surfaces that have experienced relative stability in the long-term, as in the case of some plateaus in karst areas, may have been deflated on those surfaces, although they otherwise remain more or less close to the original place of discard. In this instance, while the vertical integrity of the original artefact deposits may be lost, the lateral integrity remains relatively undisturbed (*cf.* Fanning et al. 2009, 127).

Similarly, all artefacts and sites that are now found *buried*, were once surface scatters. Because most dis-

turbances occur in the period immediately following artefact discard (Wainwright 1992, 235), it is unlikely that artefacts would have escaped disturbance if they were discarded on land-surfaces of high gradient, for the same reasons that apply to the case of the non-buried-artefacts.

Therefore, it is only in *low-gradient* and/or *depositional* environments that we can assume:

1. little disturbance after discard and before burial
2. little disturbance after discard and upon burial (*e.g.* with sediment accumulation by low-energy depositional process as in a lacustrine context)
3. little disturbance after burial and upon exhumation (*e.g.* by deflation)
4. little disturbance after discard and with no or minimal burial (*e.g.* on karstic, flat-floored plateaus, where water-related processes are mostly endorheic)

Yet, both in a large-scale (landscape-scale) perspective and in the meso-scale of the hillslope, there are landforms and slope-classes that fall into an 'intermediate' qualitative category. This would include mainly slope gradients of 2-4 degrees or more, and landforms formed *e.g.* as hilly alluvial or fluvio-lacustrine units and alluvial/colluvial fans (although the latter may display even greater gradients). Existing badlands, exhibiting inclined to strongly inclined slope angles, can also be viewed as potentially belonging to these 'transitional' realms, with respect to their role in archaeological preservation and visibility. For instance, during the times when early hominins were moving around the ephemerally lacustrine environment of Kokkinopilos, the topography of this tectonic basin (polje) most probably ensued a depositional environment of generally low-gradients and low-energy geomorphic processes (hence, in accordance with the assessment about preservation- and context-wise advantages of basins). When the polje was subjected to the tectonic activity triggered by the adjacent fault, uplift caused stream incision and dissection of the basin-floor, gradually developing the characteristic badland landscape that we see today. The present-day micro-environment of Kokkinopilos is one of constant and rather vigorous erosion, which changes the local topography in time-scales of years or even months; and yet, there are considerable opportunities for recovering *geologically in situ* arte-

facts from non-reworked deposits. In short, landscapes and landforms with a biography such as that of Kokkinopilos, and perhaps also alluvial fans that are being -or, have recently been- dissected by incising streams, may overall serve as 'windows of opportunity' for recovering material from a geologically relatively undisturbed context. In that respect, they should not be underrated because of their steep gradients. Such 'windows' may potentially combine those two highly-valued and usually ill-assorted geoarchaeological conditions: a good degree of preservation and a high grade of visibility.

This is mainly why a geomorphological approach acquires a crucial role in the armory of archaeological methodology, for geomorphological indicators are capable of dictating both a qualitative and a quantitative allocation of efforts in archaeological research, by pinpointing:

1. areas that are promising for surface survey, *e.g.* extant stable surfaces of low-gradient, such as karstic plateaus
2. areas that may be appropriate for subsurface investigations, *e.g.* places where aggradation was predominant during and/or after the time-span of interest, such as a floodplain or a lacustrine setting, especially if recent (Holocene) erosion has exposed sections and palaeo-surfaces
3. areas that should be deemed unpromising for neither of the above, as places where neither stability nor aggradation, but, rather, erosion predominated during and/or after the time-span of interest.

A slope map is but one morphological measure that can be used to assess archaeological potential for preservation and recovery as a function of surface stability. At the regional level, stability classification is a powerful tool for both predicting and interpreting artefact and/or site distributions. To this end, the application of morphostratigraphic and/or allostratigraphic mapping assists in considering forms and processes in conjunction, thereby "classifying the landscape into surfaces whose form indicates a dominant depositional or erosional process for a discrete period of time" and "combining the surface morphology with the subsurface stratigraphy" (Wells 2001, 110-13). In this line, the slope map of Greece that I present here, as well as the discussion around it, can be

regarded as an example of the methodological approach advanced in this study not only when assessing the current status of the Greek Lower Palaeolithic record, but also in addressing pathways for ‘the way forward’ in future investigations.

6.6 CONCLUSIONS

In accordance with the most up-to-date assessments of erosion in the Mediterranean in general and Greece in particular (*e.g.* Grove and Rackham 2001; Thornes 2009; Wainwright 2009), the examples and evidence outlined in this section altogether suggest that the terrestrial environment of Greece is largely prone to erosion, and it has most probably been even more so in the course of the Quaternary. The reasons behind such a high susceptibility to erosional processes are tightly interconnected by various generic dependencies and feedback mechanisms, and so the challenge here was to examine those complex parameters both in conjunction and as separately as possible.

Thus, section 6.2 highlighted seasonality, precipitation and the seasonality of precipitation as the major climatic attributes influencing slope and fluvial erosion. The present-day mode of seasonal river flow fluctuations and the seasonality of runoff would have been even more pronounced during the Pleistocene (*viz.* mostly during cold stages), accentuating the steepness of river hydrographs, *i.e.* increasing the ephemerality of flow regimes and decreasing the recurrence intervals of discharge peaks, thereby intensifying both frequency and magnitude of short-lived extreme events (*e.g.* floods). The geo-archaeological implications would be reflected in an enhanced coupling of the slope-channel systems, very rapid time-spans of incision/erosion and alluviation episodes, and hence reworking of artefact accumulations in alluvial/fluvial sediments every few thousand years. In the long-term, phases of landscape instability would mainly coincide to climatic transitions at both orbital (millennial) and sub-orbital (centennial/decadal) time-scales, and most notably during cold-to-warm transitions. In sum, although vegetation and rain-erosion maps defined also a spatial aspect, this chapter stressed primarily the *temporal dimension* of landscape (in)stability and erosion, namely the temporal windows of erosion/deposition, their possible durations, as well as the frequency of recurrence.

Section 6.3 explored tectonic controls putting the emphasis on the *spatial dimension*, as revealed in different scales of analysis: in a large-scale perspective, extensional tectonics and associated subsidence provided the necessary accommodation spaces for the bulk of the sedimentation occurring during the Quaternary, configuring the nature and extent of drainage basins. In the meso-scale, uplifting regions in compressional regimes (*e.g.* Western Greece) and areas that were parts of footwall-blocks in extensional regimes (*e.g.* Central Greece) have been mostly subjected to erosional processes, and basin inversion was stressed in this regard with particular reference to two case-studies (Gulf of Corinth and Megara Basin). Finally, the tectonic control on syn- and post-sedimentary processes was considered with regard to specific examples of drainage diversion/incision, as well as with reference to the effects of faults and earthquakes on slope development, landslide triggering and mass failures.

Whereas climate and tectonics constitute the main exogenetic and endogenetic driving factors in landscape evolution, their various interactions are manifested on the land-surface as slope processes. Main aspects of the latter were examined in section 6.5, where a slope map of Greece was presented as a means of visualizing and extracting general spatial trends of erosion, with the aim of exploring geomorphological and geoarchaeological patterns of preservation and visibility. Notwithstanding the coarse resolution and the speculative nature of this appraisal, it was argued that geomorphological opportunities for a relatively high degree of site preservation (also context-wise) is restricted to some one fourth (or, one third, at most) of the total area of the country, where low-gradient depositional settings occur. As it was shown, such an assessment finds strong support when considering the landscape under the perspective of the nine-unit land-surface model.

As a whole, these analyses largely explain why the Greek Lower Palaeolithic record is scanty, mainly surficial and rarely found in buried deposits: this picture is most probably a consequence of the prevalence of erosional rather than depositional landforms and land-surfaces. In addition, it can be argued that the fragmented nature of both the geological and the archaeological record before around MIS 6 is not a

coincidence: it can be seen as reflecting an eco-geomorphic system dynamic and/or unstable enough to have considerably prevented adequate preservation of landforms and associated archaeological material *before the last interglacial-glacial cycle*. It is well-known that in north-western Europe, the severity of (some) glaciations erased the geological traces of earlier glacial and/or interglacial stages, biasing the geological archive in favor of the most recent stages. For Greece, it has already been shown that the geomorphological implications of the most severe glaciations would have been disproportional to the small size of the equivalent glaciers (*e.g.* Woodward *et al.* 2008). Even if we neglect the advance and retreat of glaciers as potential biasing agents as in the case of north-west Europe, the argumentation developed in this chapter (and most notably in sections 6.2, 6.3. and 6.5) indicates that there is still much evidence to suggest that short-lived but high-amplitude extreme erosional events, mainly accompanying climatic transitions, would have been capable of eradicating and/or *reworking* sedimentary units of previous glacial-interglacial cycles -to such an extent that the geomorphological imprint of warm and cold stages before the last interglacial are only discontinuously preserved today, mostly as erosional rather than depositional landforms.

Triggered either by climatic (*e.g.* deluges), tectonic (*e.g.* earthquakes) or, lately, anthropogenic agents (*e.g.* land use), it is indeed principally those episodic but catastrophic events that induce most of landscape instability, with landslides, slope failures and river incision being some of the main geomorphic responses. The validity of this assertion has acquired a wider acceptance for active tectonic settings with a susceptible terrain of high-relief and an eco-geomorphic system that responds rather fast to climatically generated disturbances, and it has been supported by studies of both past and present erosional phenomena in Greece and landscape development in the Mediterranean (*e.g.* Cendero and Dramis 1996; Martin and Church 1997, 278; Mulligan 1998; Kosmas 1999b, 19; Kirchner *et al.* 2001, 593; Grove and Rackham 2001, 247-252; Montgomery and Brandon 2002; Bintliff 2002; Macklin *et al.* 2002, 1638; Goldberg and Macphail 2006, 77; Koukis *et al.* 2009; Thornes 2009; Wainwright 2009, 190).

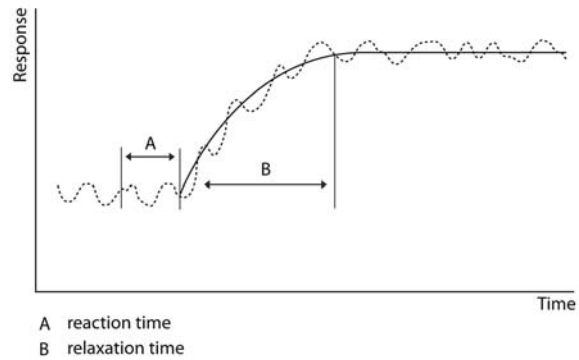


Fig. 6.28 Simplified graph showing the response of a geomorphic system subjected to disruption (after Imeson 1986: fig. 5). If a new disturbance occurs before the relaxation time is completed (*i.e.* within the time-span represented by 'B' in the graph), transient (unstable) forms will prevail.

Much as it is conceptualized in theoretical frameworks (*e.g.* Brunsden and Thornes 1979) Quaternary landscape evolution in Greece can be viewed “as a series of short adjustments between constant process-characteristic form states” (*ibid.*, 481), where landscape change was mainly episodic and marked mostly by temporally discontinuous large-scale disruptions. Overall then, erosion may have not been prevailing for most of the time, but the combination of tectonism, increased seasonality, steep relief and erodible lithologies, altogether pre-conditioned ‘windows of opportunity’ for extreme erosional episodes to occur.

Referring to the impact of vegetation change on the Mediterranean fluvial systems, Macklin and colleagues (1995, 12) note that “a steady-state can neither be reached, nor maintained, if the relaxation time of the system is longer than the mean recurrence time of the disturbance to it” and that “an abrupt or step-functional change of this nature [*i.e.* millennial-centennial climatic fluctuations] would undoubtedly have exceeded both vegetation and soil system’s capacity for adjustment, triggering a period of landscape instability with high erosion rates, valley floor aggradation and river metamorphosis”. The researchers note also that although this scenario appears very likely, the low resolution of fluvial chronologies prevents a direct confirmation. Essentially, Macklin and

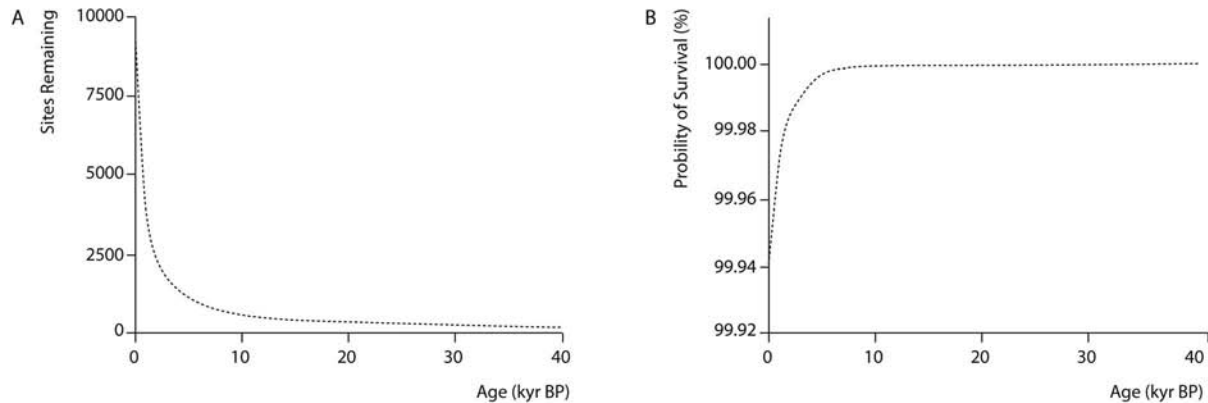


Fig. 6.29 Main results of the model of taphonomic bias, after Surovell *et al.* 2009: fig. 2. A: the predicted loss of archaeological sites over time assuming 10,000 sites at time zero; B: the annual likelihood of survival as a function of site age. Note that, in both (A) and (B), a marked change in the curve occurs at around the time-point of 10,000 years

colleagues' statement addresses the issue of landscape sensitivity (Fig. 6.28). The latter is concerned with whether transient or persistent (stable) landforms prevail under given circumstances and can be assessed by comparing landform or ecosystem relaxation time with the recurrence interval of vegetation or geomorphic disturbances (Brunsden and Thornes 1979, 480; Phillips 1995, 338-340). According to the transient form ratio (TF_r) introduced by Brunsden and Thornes (*ibid*), $TF_r = t_a / t_f$, where t_a and t_f are the mean relaxation and recurrence times, respectively. A ratio greater than unity indicates the prevalence of transient forms, whilst a ratio less than unity suggests that characteristic, stable forms will prevail. In other words, the system cannot attain stability (and/or steady-state) if a new disturbance occurs before the relaxation time has elapsed (the latter denoted as B in the scheme of Fig. 6.28). As it is explicitly stated by Macklin *et al.* (see above), this could have been the norm in the Mediterranean during the Quaternary due to the perturbations induced by climatic fluctuations at millennial, centennial, or even decadal scales. Also, tectonics would have contributed to such disturbances with a short recurrence time⁶⁴. Although the task of mapping the sensitivity of landscape components in Greece during the Qua-

ternary will remain unrealistic for the near future – hence hindering a confirmation of this assumption, it is tempting to assume a marked unsteadiness or transient behavior of the landscape in Greece over periods of 100 to 10,000 years during most of the Quaternary (*cf.* Brunsden 2001; Phillips 2005, 2006; Bishop 2007).

In a study of how taphonomic bias affects temporal frequency distributions of archaeological sites and dates, Surovell and Brantingham (2007) explored a basic geoarchaeological argument, namely that the probability that something will be removed from the geological/archaeological records is a function of time, which in turn causes an over-representation of recent events (or, sites) relative to older events. Building on the idea that taphonomic bias can be evaluated by examining the ratio of archaeological to geological contexts, Surovell and colleagues (2009) demonstrate that, in contrast to the results of their previous work, the rate of site loss does not remain constant through time, but instead declines with site age (Fig. 6.29).

The latter finding agrees well with the notion mentioned previously that a site is most at risk of being destroyed by surface processes during or directly after the time of abandonment, when material rests at or near the surface (Surovell *et al.* 2009, 1718). According to the model of Surovell *et al.*, “if a site can survive its first 10,000 years of existence, its annual probability of destruction is reduced to approxi-

64. As an indication, let us recall here that the recurrence frequency of strong earthquakes (Magnitude >6 in the Richter scale) was estimated to be one every 1.7 years for the past 2,500 years (Caputo *et al.* 2006).

mately 0.01 %” (ibid). This 10^4 -years sort of ‘threshold’ emerging from that model brings to mind the landscape-sensitivity argument discussed above: if the vast majority of landscape components in Greece acquired a transient (unsteady) behavior over periods of 100 to 10,000 years for the most part of the Quaternary, then archaeological sites would have fewer chances for surviving their first 10,000 years of existence -and hence improving thereafter the likelihood of survival up to the present.

In order to assess taphonomic bias on the spatial extent of the Lower Palaeolithic geoarchaeological record, we must consider the total area of Greece as the *potentially initial extent* of that record. To this, we would have to add the areas emerging during glacial sea-level lowstands (as well as during some interglacials *e.g.* that of MIS 11, and earlier ones; see Fig. 6.18 above); those areas have a total extent that approximates that of the current mainland (*ca.* 130,000 km²). Since those latter areas are now submerged, we can consider that only about half of the initial record is theoretically today at the disposal of archaeologists for investigations. According to the arguments presented in section 6.5, potential areas for preserving the record are restricted to about 40% of half (50%) of the initial record, namely some twenty percent altogether. This twenty percent mainly represents the low-gradient, sedimentary basins, which have been hosting the bulk of sediment accumulation during the Quaternary. However, much of the latter value (the total area of the basins) corresponds to Holocene surficial sediments, since a large part of Pleistocene sediments lies now at great depths, as it is the case with the stacked alluvial sequence of Thessaly, where exposed Early and Middle Pleistocene sediments occupy only 0.8% of the total extent of the basin. Moreover, for another fraction of the basins it is pre-Pleistocene deposits that are exposed on the surface, as in the case of many depressions in northern Greece. According to Koukis and Ziourekas (1991), Quaternary formations occupy 15.8% of the total area of Greece. In the most optimistic assessment, Pleistocene sediments would thus cover about 10% of Greece, the rest 5.8% representing Holocene deposits. In effect, Pleistocene sediments cover today a spatial extent which corresponds to 10% of the 50% of the potentially initial extent of the record, namely some 5% of the latter; note that

this assessment is independent of the geoarchaeological / geomorphological appraisal on the spatial coverage of potentially promising areas. If we do consider the geomorphological argument, then areas promising for preserving the record would amount to:

10% (= Pleistocene deposits) of the
40% (= low-gradient depressions including pre-Pleistocene and Holocene sediments) of
50% (= current continental extent of Greece)
= 2% of the potentially initial extent of the Lower Palaeolithic geoarchaeological record.

The premise of an ‘initial extent’ is not entirely arbitrary, but it *is* dependent on time: the initial extent of double the size of Greece is best applied to time-periods before *ca.* 400-500 ka, when emerged areas in the Aegean attained their maximum coverage during sea-level lowstands. After MIS 10-12, this ‘initial’ value would be smaller (*viz.* the emerged areas were more restricted) but the final outcome of the estimate would not be much bigger (*i.e.* a larger percentage left (as promising) for investigations). When considering the geomorphological argument based on relief, the concluding amount is still small, even if we regard the ‘initial extent’ as equaling that of Greece’s current area:

10% (Pleistocene sediments) of the
40% (low-gradient, same as above) of the area of Greece
= 4% of the ‘initial record’ (and of the area of Greece in this scenario).

I believe that possible miscalculations due to the ‘roughness’ of the assessment would be averaged and cancelled out, and anticipate that more accurate calculations based on higher-resolution data would probably yield even smaller percentage values. In fact, it can be argued that for both of the above scenarios (pre- and post-500 ka assessments) the above-estimated final amounts could be viewed as maximum evaluations. For example, Early and Middle Pleistocene sediments, which are now either exposed on the surface or buried by relatively thin overlying sequences, would cover some 5%-10% of the total area of the basins; put differently, most of the spatial extent of exposed Pleistocene sediments in Greece refers to Late Pleistocene deposits.

In sum, from a hypothetical initial extent of the Lower Palaeolithic geoarchaeological archive in mainland Greece and the Aegean at almost any given datum in the Early and Middle Pleistocene, what has been (potentially) preserved until the present covers no more than five percent of the Greek mainland. This is admittedly a coarse estimate, but it provides a good indication of ‘how much has been lost’; in that sense, it allows for a more objective explanation of why the Lower Palaeolithic record of Greece is so scarce. Furthermore, it is, in the main, a quantitative assessment with a semi-qualitative additional character: it quantifies in spatial terms the potential for artefacts to have been preserved in a primary and/or secondary context. However, this evaluation does not necessarily include all areas that combine *both* high preservation potential *and* good archaeological visi-

bility (exposure). Examples of the latter situation were given with regard to inverted basinal settings: the Corinth Gulf and the Megara basin were discussed as case-studies of the meso-scale, whilst Kokkinopilos exemplifies this sort of ‘window of opportunity’ in a smaller-scale. For all of those cases, it was stressed that the critical factor lies in the mode, onset (timing) and duration/intensity of erosion since the initiation of uplift and the resultant basin inversion/drainage diversion, incision and exposure of low-gradient depositional settings that -until then- remained buried and protected. Differences in this critical factor may be able to explain the paucity of the Greek Lower Palaeolithic record as opposed to that of, for instance, Italy or Spain –a hypothesis that is discussed below, in the final chapter of this thesis.

7– Synthesis

7.1 INTRODUCTION

In the beginning of this book, chapters two and three outlined the main aspects of the Lower Palaeolithic (LP) period and the earliest hominin movements between Africa and Eurasia (and/or within Eurasia itself). Specifically, the overview of key-sites of the circum-Mediterranean region in chapter three focused chiefly on patterns regarding the existing regional chronological schemes, the nature and credibility of the archaeological evidence, and the geomorphological settings and depositional environments in which the latter is attested. In turn, this review provided the framework against which the Greek testimony was put under scrutiny in chapter four. Here, a critical re-appraisal of the LP data-set was given –the first to appear in the literature after the discovery of the Petralona cranium and the handaxe from Palaeokastro in the 1960’s, which provoked the earliest claims for a pre-Mousterian human presence in Greece. As in chapter three, the guiding principle for this comprehensive evaluation was that ‘stratigraphy is the only truth’ (*cf.* Dincauze 2000). To ‘work’ this motto, fieldwork was carried out in the two most important sites; although limited by practical constraints and permit issues, the results from my revisits of Kokkinopilos and Rodia enhance our understanding of those sites and highlight their role as promising targets for future investigations. Fieldwork-based experience was used also in chapter five, where preliminary results from survey projects in Macedonia and Zakynthos were presented; here, it was demonstrated that the difficulty in finding material stratified into Early and Middle Pleistocene deposits is mostly due to geological biases, rather than research-related issues (*e.g.* research intensity, designs and objectives, or expertise of participants). Thus, chapter five bridged the conclusions from the examination of the Greek LP record with the exploration presented in chapter six: the evolution of

the Greek landscape during the Quaternary, and how it might have affected the preservation of the archaeological record.

Below, a synthesis of these results is presented in four sections, which cover equivalent thematic categories, in turn related to the primary research questions of this study: the first section (7.2) refers to the evaluation of the Greek LP record, both in its own right and in juxtaposition with patterns emerging from the rest of the Mediterranean; the second section (7.3) explains the status of the record on the basis of the geo-archaeological and geomorphological approach advanced throughout this study, emphasizing at the same time how geomorphic factors constrain what we should expect for Greece to yield in the future. Elaborating in this latter point, section 7.4 brings in conjunction specific proposals that were put forth for specific cases in Greece (*e.g.* Kokkinopilos/Epirus and Rodia/Thessaly) with conclusions distilled from the examination of the other LP Mediterranean records, aspiring to put in prospect the future of Lower Palaeolithic investigations in Greece, by suggesting not only methodological strategies but also places that emerge as promising targets for future research. Finally, the last section (7.5) provides a brief account on alternative and/or complementary research questions that were not elaborated here due to space limits, and outlines potentially wider implications of the perspective expanded in this study.

7.2 IDENTIFYING THE CURRENT STATUS OF THE GREEK LOWER PALAEOOLITHIC

On the most solid age estimates that we have so far, namely the dating evidence for the Petralona cranium in Macedonia and the finds from Kokkinopilos in Epirus, the earliest peopling of Greece occurred sometime between *ca.* 350-200 ka. In Thessaly, Ro-

dia provides sound artefactual evidence for a core-and-flake typo-technological facies in which Mousterian traits and the Levallois technique are absent; as such, this assemblage could be attributed to the Lower Palaeolithic. Yet, the chronological bracketing of the site relies on relative dating, based on a fossil occurrence (*Archidiskodon meridionalis*) and a U/Th date (<210 ka), both of which are not directly related to the context of site FS 30 at Rodia. On the other hand, my re-evaluation of the site confirms the proposed correlation between the Rodia gravels and those of the highest (and hence oldest) river terrace in the area. Moreover, following the suggestions of R. Caputo, who has defined the locally exposed Rodia Formation, I pointed out the possibility that the FS 30 gravels are part of this late Pliocene-Early Pleistocene Formation. If the Rodia artefacts are indeed associated with the upper part of the Rodia Fm, then it is Rodia that has yielded the oldest human traces in Greece, most likely dating to the Early Pleistocene. Until this is confirmed, *there is no unequivocal evidence for an Early Pleistocene human presence in Greece*.

However, the fossil remains from Petralona and Megalopolis (and, in all probability, also those from Apidima) demonstrate the presence of humans in the late Middle Pleistocene, and *most likely even before ca. 200-300 ka*, if we account for the morphology of the Petralona cranium (e.g. affinities with the Sima de los Huesos material; Harvati 2009) and the age of the Marathousa Member at Megalopolis (>300 ka; van Vugt *et al.* 2000). The late Middle Pleistocene is a period of significant biological developments in hominin lineage(s), notably with regard to important steps in the 'Neanderthalization' process (Hublin 2002; 2009). While the phylogenetic assessment of the Megalopolis tooth is pending, the Petralona specimen shows that *H. heidelbergensis* was certainly present in Greece, whilst the Apidima fossils may be pointing to representatives of (other?) 'early' or 'pre-Neanderthals', if they are not *H. heidelbergensis* (*sensu stricto*), too. Currently, the latter species can be considered as the most probable maker of the existing non-Mousterian Middle Pleistocene material remains in the Greek Peninsula, although I have already stressed how tentative such associations usually prove to be. Exactly because we need to be cautious before equating hominin species with cultural

periods/artefactual taxonomies, we cannot *a priori* assume that the hominins of Petralona and Megalopolis were using a lithic tool-kit that we would conventionally ascribe to the Lower Palaeolithic. *In this sense*, and as we have to exclude Rodia for a most conservative assessment (see 4.6.4), the only secure Lower Palaeolithic evidence from Greece is so far restricted to the handaxe (and associated artefacts) found by Runnels and van Andel in Kokkinopilos. The stratigraphic position of the latter, the age estimate based on the TL-dated paleosol capping the entire sequence, and the absence from the artefact-bearing layer of any specimens indicative of prepared-core technological features (in a site with a strong Levallois signal), altogether support this conclusion. Refinement of the local chronostratigraphic framework, further confirmation of the stratigraphic integrity of the site and more systematic collection of stratified artefacts, will corroborate whether there is indeed a Lower Palaeolithic component at Kokkinopilos (as suspected and argued here), *or* whether we have been looking at an early Middle Palaeolithic facies with handaxes.

Besides the general lack of stratigraphic control, the fact that the earliest best-dated human and material remains in Greece date to between *ca.* 350-150 ka complicates even further any attempts to ascribe undated surface assemblages to either the Lower or the Middle Palaeolithic. This is the time-span during which the transition between the two periods appears to occur in most of Europe. Apart from noting the complexity in identifying, assessing and comparing 'transitional' industries, it is not possible to discuss here the character of this transition in Europe (which still remains largely enigmatic), much less to compare it with the limited evidence from Greece or the Balkans (*cf.* Reisch 1982). Likewise, the nature of the material from Greece (small sample, undated surface collections) obscures the identification of any meaningful pattern with regard to the Mode I versus Mode II spatio-temporal distribution. Taking the Lower Palaeolithic of Greece at face value, it emerges with Mode I tool-kits; in that respect, it follows what some researchers opt to recognize as a general pattern for the earliest circum-Mediterranean sites. In fact, when adopting a less strict perspective for ascribing material to the Lower Palaeolithic, then, all assemblages from Greece thus far attributed to

this period are ‘core-and-flake’ industries (*i.e.* Rodia, Nea Skala, Alonaki, Petralona, Doumbia, Milos). On the other hand, the specimen that *chronostratigraphically* provides the best ‘Lower Palaeolithic’ evidence is a handaxe. Rough cores and choppers have been found also in later contexts (*e.g.* Panagopoulou 1999) and it is overall not clear whether Mode I industries truly precede the earliest Acheulean in Greece. The fact that all of the Greek assemblages mentioned above are of Mode I type may partly reflect the biased notion that morphologically simple tools are of early age. Considering the finds from Kokkinopilos (Runnels and van Andel 1993a; Tourloukis 2009) and perhaps also those from Crete (Strasser *et al.* 2010), it is now beyond doubt that (Acheulean) handaxe manufacture was practiced in Greece most probably already in the Middle Pleistocene, persisting well into the Middle Palaeolithic. Accounting for the small sample of Lower Palaeolithic finds and the harsh preservation conditions, the presence or absence of bifaces in Greece cannot be as yet adequately explained and it apparently varies regionally for reasons other than ‘cultural’ (see *e.g.* Runnels 2003b for an environmental explanation of the distribution of core-chopper versus handaxe-dominated assemblages in SE Europe and Turkey). Industries dominated by core-choppers are being found in western Greece alongside handaxes (the latter being, though, mostly solitary finds), as for example in the area of Alonaki. All in all, we can envisage the earliest inhabitants of Greece using non-specialized tool-kits in employing subsistence strategies within a highly diverse and mosaic landscape; and there would have been room for both Acheulean and core-like implements to be alongside (or, interchangeable) in these tool-kits, without the need to assume different populations.

Apart from the caves of Apidima and Petralona (see below), the geomorphological setting of Kokkinopilos is that of a tectonic depression (a polje), whilst Rodia is situated in the margins of the Larissa basin, at the point where the Pineios river enters a gorge. The sedimentary sequence of Kokkinopilos accumulated in the environment of an ephemeral lake, whereas the fluvial gravels of Rodia most likely represent river-bar deposits. The rest of the sites with possible Lower Palaeolithic material are associated with fluvial/alluvial settings (Aliakmon localities,

Higgs’ handaxe from Palaeokastro and Doumbia in Macedonia, and the findspots on the terraces of the Peiros in Peloponnesus); whilst Alonaki and other findspots of Epirus (Ayios Thomas, Ormos Odysseos) are in solution basins with fills of redeposited *terra rossa*, or in coastal plains; the marine terraces of Nea Skala and the Triadon Bay of Milos also belong to coastal settings. In terms of both geomorphological settings and depositional environments, the Greek evidence matches exactly the pattern deduced from the rest of the Mediterranean records: the vast majority involves open-air sites, found within topographic depressions at low elevations and with low gradients, such as drainage catchments, former lakes and coastal areas; hence, the archaeological material is commonly associated with fluvial, lacustrine or fluvio-lacustrine contexts. The location of FS 30 at the Rodia Narrows and close to the point where the Titarissios river meets the Pineios, brings to mind the patterned association of Iberian sites with river confluences and valley entrances. Within the karstic, rugged landscape of Epirus, Kokkinopilos documents repeated visits of hominins at an ephemeral lake close to the river Louros and reminds us of the mosaic environments in which the Italian sites are located, in the Apeninnic basins, whilst from the perspective of its geomorphological setting, it would not be very dissimilar to that of Ambrona (Spain). The Early and Middle Pleistocene basinal setting of Megalopolis would be comparable to that of Isernia and Notarchirico (Italy), the sites of the Guadix-Baza basin (Orce, Spain) or the Levantine sites of ‘Ubeidiya and Gesher Benot Ya’aqov. Importantly, Middle (and occasionally Upper) Palaeolithic evidence from the poljes of Epirus (*e.g.* Kokkinopilos, Karvounari, Morphi), and from other depressions, such as the Thessalian basin or that of Mygdonia, indicate that hominins continued to exploit the rich resources of those basins also in the Late Pleistocene (*cf.* Runnels and van Andel 2005) – a pattern that was stressed with regard to the Italian record as well.

The scarcity of Lower Palaeolithic cave sites is as conspicuous in Greece as it is in the other Mediterranean records; exceptions such as Petralona, Yarımburgaz (Turkey) or Kozarnika (Bulgaria) only serve to confirm the norm. The age estimate for Petralona follows the general trend of cave use being a rather late phenomenon. The cave of Apidima and other

cave sites with younger material in southern Peloponnesus (Lakonis, Kalamakia) are here to remind us that, if coastal caves were as important in the Early and Middle Pleistocene as they appear to have been in the Late Pleistocene, then we have certainly lost a lot due to marine inundations of the present or earlier interglacials; let us recall here the assertion by Pitsios (1996) that less than 5% of the original volume of Pleistocene deposits remain today in Apidima. Although the submergence of coastal caves is the most dramatic demonstration of preservation biases, there is another issue to consider in this direction: some Lower Palaeolithic cave sites and cavities have infillings with sediments washed in from the surroundings (allochthonous deposits), as it is the case with Sima de los Huesos and Sima del Elefante in Atapuerca, Pirro Nord in Italy and Le Vallonet in France; for those, it is hard to make an argument for hominin preference for caves. In contrast, if we accept that the half-lives of caves average about 250 ka (Wrangham 2009, 88)⁶⁵, and that coastal caves would have been preferred over upland ones; then, it is reasonable to argue that the observed rarity of cave use before the late Middle Pleistocene partly reflects preservation biases. Moreover, there are a number of behavioral factors that could have constrained the use of caves: for instance, control of fire may have been a prerequisite for cave dwelling (*cf.* Mussi 2001, 85), while lack of appropriate weaponry would have limited confrontational success in encounters with carnivores. Combined, these factors alone would have emplaced a high risk level for the use of caves. Hence, both the 'late' dates for Petralona and Apidima and the overall scarcity of caves with pre-Late Pleistocene deposits in Greece is not a surprise.

But the overall results from the re-evaluation of the Greek Lower Palaeolithic evidence are indeed a surprise, and a negative one, considering what the rest of the Mediterranean records should let us expect from the Greek Peninsula. Hominins were certainly present in Greece in the late Middle Pleistocene, most probably before *ca.* 200-300 ka and in all likelihood

associated with a Lower Palaeolithic material culture. Yet, the soundest dating evidence from the best-studied sites, namely Petralona, Kokkinopilos, Megalopolis and Rodia, is still inadequate to confidently dismiss the question mark standing next to the 'Lower Palaeolithic' label. In a sense, Rodia exemplifies the problems with the status of the Greek Lower Palaeolithic: even when the dating combines different lines of evidence, such as biostratigraphic indications (the elephant fossil); radiometric results (U/Th); secure-enough geomorphological correlations (fluvial terrace stratigraphy); chrono- and lithostratigraphic evidence (Plio-Pleistocene Rodia Formation); and tectonic history (the age of the associated faults); even then, the desired degree of certainty is missing. Is this a 'technical' issue? Methodological constraints on dating techniques are undoubtedly at stake: a successful dating program at (most prominently) Kokkinopilos or Rodia would perhaps suffice to clear the picture. However, as I already argued, the scarcity of sites and the lack of stratigraphic control are more than technical issues and cannot be sufficiently explained by research-related biasing factors. As deduced from the conclusions of chapter three, the same (or very similar) dating-related problems that tantalize the late Middle Pleistocene record of Greece affect most of the Early and early Middle Pleistocene circum-Mediterranean key-sites as well. Obviously, in lack of excavated sites, the Greek evidence cannot be directly juxtaposed to that from the rest of the Mediterranean; that is, not in even terms. Having said that, I would still argue that the main issues that the Mediterranean sites are facing, are the same issues bearing on the Greek record, except in a different time-frame: if for the other Mediterranean sites chronological data and context-related arguments become increasingly problematic the further we reach back in the Early Pleistocene, the same applies to Greece, but in this case the problems start already from the lowermost end of the Middle Pleistocene, if not the Late Pleistocene. For instance, why is it that Upper Palaeolithic sites in Greece are so few (see *e.g.* Runnels 1995), with only a handful of open-air find-spots yielding mostly non-stratified material? And how do we explain the fact that, apart from the five main excavated caves, the Middle Palaeolithic open-air sites remain in their majority undated and largely comprise of surface material (see above 4.1), which is found commonly mixed with artefacts from later

65. Note, however, that a recent dating study of cave sediments in Slovakia showed that deposits in caves (both clastic and chemogenic) can be up to several millions of years old (Hanja *et al.* 2010, 49).

periods? Very little is known even for the Greek Mesolithic, with inland open-air sites being extremely scarce (see *e.g.* Tourloukis and Palli 2009). Below I will discuss how the role of geomorphic processes explains this fragmented geo-archaeological archive, keeping the focus on the Early and Middle Pleistocene and using the Italian and Iberian records as case-studies for informative juxtapositions.

7.3 EXPLAINING THE CURRENT STATUS OF THE GREEK LOWER PALAEOLITHIC

‘Ice Age’ is a popular term to describe the Pleistocene Epoch, but it is not far from the truth if we consider that temperate stages account for only about 10% of the Pleistocene. Hence, for most of the last 2.5 myr, relatively harsh climatic conditions prevailed, and it has been shown that during these cold periods, plant, animal and probably also human European populations would retreat to refugial areas in the southern parts of the continent, Greece being certainly one of them (*e.g.* Blondel 2009). At around and after *ca.* 400-500 ka, *i.e.* exactly when the European (including the Mediterranean) archaeological records become more substantial (both quantitatively and qualitatively), large lakes were formed in the Aegean, between extensive landmasses, which emerged during sea-level low-stands of glacial spells. Before *ca.* 400-500 ka and until an Early Pleistocene datum-line that is yet to be resolved, those lakes and the emerged land would most likely have persisted also during interglacial stages. Based on recent data (Lykousis 2009), I estimated that the Aegean and Ionian subaerial land of MIS’s 10-12 would amount to *ca.* 140,000 km², *i.e.* to a total area comparable to the continental extent of Greece. The land emerged during MIS 8 was only slightly less than that of the preceding glacial(s) and only from MIS 6 onwards there would have been a significant difference in emerged aerial exposure. In brief, from most likely about the early-middle Early Pleistocene until (a cautious) MIS 8 but essentially until MIS 6, extended landmasses (in total, almost equaling what is today continental Greece) were exposed in the Aegean and Ionian Seas during both glacials and interglacials (pre-MIS 10 period), or during only glacial sea-level drops (post-MIS 10 period). Put differently, *an aerial extent that fluctuated around the size of today’s mainland*

Greece lies now submerged; or, archaeologically speaking, half of what would have been ‘the Greek record’ is currently underwater, virtually forever lost. This is the first point to consider in explaining the status of the Greek Lower Palaeolithic archive.

Besides lakes as large as -and even larger than- the size of Crete (*e.g.* in northern and central Aegean during MIS 8), we can envisage the emerged land being dotted with numerous moors, ponds, marshes, lagoons, littoral zones and, of course, rivers and ephemeral streams, which are overall not shown in the reconstruction of Fig. 6.18. In those times of ‘land emergence’, what we know today as the Aegean islands are the peaks of mountains. Although continental conditions are accentuated during marine regressions, it is mainly the water bodies setting the ecological tone of those landscapes, with freshwater, brackish and marine resources allocated in rather small distances and alternating during the emergence-submergence cycles. Due to time-constraints, it was not possible to include in this study an examination of the potential ecological productivity for those landscapes. Yet, most scholars would likely be ready to attribute a high ecological value to environments combining a strong marine influence with most beneficial features of terrestrial ecosystems (freshwater lakes, rivers, etc). Exactly such an environmental structure would have constituted the most efficient buffer to the effects of glacial climatic extremes. Spatially and temporally variable marine incursions in the short-term and the cyclic alterations of regressions-transgressions in the long-term would most probably have enhanced also topographic complexity, which in turn serves as a spatial buffer to acute climatic conditions (Loarie *et al.* 2009). Discussing the ecological importance of the poljes of Epirus, Runnels and van Andel (2003, 77) note that “If the resource potential of an environmental zone is assumed to be roughly equal to its area, most of the time [in their case: over the past 130 kyr] the coastal plains were at best equal in potential to the combined area of all poljes”. Assuming the same for the emerged Aegean and Ionian landscapes, their ecological significance becomes immediately obvious. In short, those landscapes would have served as:

1. Refugia during periods of increased climatic stress

2. Corridors for animal, and, most notably, hominin population movements
3. Super-ecotones (*cf.* Bailey *et al.* 2008), hence ideal habitats for hominins, and, generally, areas of broader archaeological and palaeoanthropological significance, as potential sources of evidence for biological adaptations and behavioral innovations.

Considering all the above, I would argue that those areas would have been the best places to be exploited by hominin groups arriving in the wider Aegean region. A marine control on sedimentation together with the influence of the rivers of Asia Minor and Northern Greece debouching thick alluvia would have created extended low-gradient terrains of coastal lowlands, deltaic and lacustrine depositional settings and geomorphological flatlands. Hence, both of the two most important factors for today's archaeological investigations are essentially met here: hominin habitat preferences and a high degree of geomorphological preservation potential. In this sense, the fact that this part is now lost suggests that we are missing not only half of the record, but most probably *the best half of it*. This is the second point to consider in explaining the status of the Greek evidence, and it carries an extra, qualitative value: *the best chances that we would potentially have in recovering a Greek Isernia or 'Ubeidiya have been drowned by the sea – and in more than one episodes of interglacial transgression.*

In chapter six, I examined landscape dynamics as expressed in various interrelated processes between vegetation, lithology, soils, topography and land use, all of which are more or less conditioned by the ongoing tectonic activity and the seasonality of a Mediterranean climate. On the grounds of this examination, and following basic principles and empirical applications of large-scale erosion studies in tectonically active landscapes, I presented a slope-map of Greece as a morphological measure to assess biases in archaeological preservation/visibility, assuming slope angle as a surrogate for mean local relief and a proxy for evaluating long-term erosion at the landscape-scale. From a geoarchaeological perspective, it was argued that the best cases for Lower Palaeolithic material to have survived up to the present in a primary and/or secondary context are to be sought in the

low-gradient, low-altitude areas of Greece, namely in *ca.* 30–40% of the country's total surface extent. With this line of reasoning, and by accounting for the role of the emerged landmasses discussed above, as well as considering the aerial coverage of Quaternary Formations, I suggested that: assuming a hypothetical initial spatial extent of the Lower Palaeolithic geo-archaeological archive in mainland Greece and the Aegean and Ionian Seas, what is left today as 'promising' (and/or simply 'available') target for investigations is a mere two to five percent (2–5%) of the country and of the 'initial record'. The latter value essentially coincides with lowland areas of low relief and, using the nine-unit land-surface model as a heuristic tool, I proposed that it is in those areas where material is most likely to be found in a primary and/or secondary archaeological context.

This extremely small percentage-value explains vividly the status of the Greek Lower Palaeolithic record as identified above, namely the very small number of sites and the fact that the related material is commonly non-stratified and/or it is very difficult to either associate it with a geological context or demonstrate its non-reworked character. The potential for the preservation and recovery of the geoarchaeological archive (and the qualitative status of this preserved archive) depends mostly on the available geological opportunities. This is what is ultimately reflected in the assessment elaborated in chapter six and summarized above: in spatial terms, the geological opportunities in Greece allowed for only a meager 2–5% of the record to have been preserved, and, in this portion, much of the potentially preserved material is likely to be found in a reworked (secondary) context, whereas material in primary contexts may be lying deeply buried. The reasons why geological opportunities are limited and unpropitious for stratified material refer to landscape dynamics and their spatio-temporal specifics. Quaternary landscape evolution in Greece was primarily controlled by four main driving mechanisms: (1) a *tectonic activity* with rates of vertical and horizontal deformation that are among the highest in the entire Eurasia; (2) a markedly *seasonal climate* in which the seasonality of precipitation is the most important parameter, being accentuated mostly during glacials, and, in turn, affecting river flow fluctuations; (3) *sea-level oscillations* exposing and submerging large areas, at the same time

controlling sedimentation in many parts of the country (e.g. recall the case of Zakynthos); and, last but not least, as the land-surface manifestations of all of the above, (4) *slope processes* on a predominantly high-relief terrain with spatially restricted drainage basins, erodible lithologies, skeletal soils and an effectively strong slope-channel coupling. Rather than temporally continuous, landscape disturbance occurred in an episodic fashion and in the form of extreme erosional events of low duration but high amplitude and high frequency of recurrence, in time-windows that were pre-conditioned by the combined forces of some (or all) of the four above-mentioned factors. Changes to the thresholds at which a disturbance-event became effective could be due to climatic transitions (mostly cold-to-warm ones) at millennial, centennial or decadal scales, and/or associated sea-level changes (e.g. affecting base-levels of rivers); if not climate, tectonic movements would have been equally efficient as triggering factors. As a working hypothesis, I suggested that the overall landscape instability of Greece during the Quaternary can be attributed to the transient (*i.e.* unstable) behavior of the landscape over periods of 100 to 10,000 years (*cf.* Brunsden 2001). If transient landforms prevailed over periods of 10^2 - 10^4 for most of the Early and Middle Pleistocene, then sites of those times would have had less chances for surviving their first 10,000 years of existence (and hence improving thereafter the possibility of survival until the present (*cf.* Surovell *et al.* 2009). A landscape dominated by transient, erosional landforms explains well not only the overall scarcity of Lower Palaeolithic sites but also the difficulty in recovering stratified material.

Landscape dynamics in a tectonically active setting, affected by the Pleistocene climatic periodicities, might also explain an apparent dichotomy in the degree of fragmentation of the geoarchaeological archive before and after the penultimate glacial-interglacial cycle. In 2002, Macklin and colleagues presented for the first time a correlation of Late and Middle Pleistocene alluvial sequences in the Mediterranean, based on 54 securely dated alluvial units, including Greek data. Is it a methodological bias (e.g. dating constraints) that “both the number of alluvial units, and the precision to which they are dated, decrease significantly prior to the OIS 6/5e

boundary”, as the authors note (*ibid.*, 1636), and that their oldest-dated aggradation event is identified within MIS 6? A major MIS 6 alluviation episode is documented also in the Voidomatis glacio-fluvial record, represented as the thickest and most extensive of all local units; but fluvial sediments predating MIS 6 (the latter correlated with the ‘Vlasian Stage’ of the local glacial record), have been either not preserved or buried below ‘Vlasian deposits’. My own field-work-based observations (*cf.* assessments for the Thessalian fluvial sequence, or the observed general lack of terrestrial deposits before the last interglacial in Zakynthos) suggest that such a phenomenon appears to be rather widespread in Greece. In contrast to the indications for significant terrestrial responses to climatic events during MIS 6 (which was the most extreme glacial in Greece after MIS 12; Tzedakis *et al.* 2003b) and within the MIS 5 complex (e.g. river aggradation at MIS 5d and the 5b/a boundary; Macklin *et al.* 2002; extreme phase of open vegetation during 5b; Tzedakis 2005); MIS 8 displays the least extreme Arboreal Pollen minima of the last 450 ka in the Tenaghi Philippon record. Future research may test if the subdued glacial conditions of MIS 8 and both the preceding and following interglacial complexes of MIS 9 and 7 altogether comprised a time-window for a successful hominin colonization event and/or demographic growth in the Greek peninsula. After all, the scarce dating evidence that we have at the moment for a Middle Pleistocene human presence in Greece, fall into this time-span. Alternatively, any future proof for a ‘clustering’ of sites within this period (MIS 9 to 7/6), may also serve to remind us how much filtering of the archaeological signal occurred due to the erosional processes active during MIS 6 and/or 5d to 2. In other words, it is not unreasonable to assume that very little Lower Palaeolithic material may have managed to survive more than one or two full glacial-interglacial cycles –and much less to continue to be in an *in situ* position until today.

Without such *in situ* occurrences and lacking information that can be extracted from excavated sites (e.g. data for environmental reconstructions), it is not easy to explain the association of Greek sites with areas related to water bodies (rivers, lakes, coastal zones): it probably reflects both geological preservation and hominin preferences. If it is difficult

to assess the exact importance of these two factors for records as well-studied as the Italian or the Iberian (see above 3.2, 3.3 and 3.7), this is even truer for the scanty Greek archive. However, I already emphasized how specific aspects of tectonic evolution and topographic configuration adequately explain the preservation and recovery of sites in Epirus (*e.g.* Kokkinopilos, Alonaki), and how the tectonic history of Thessaly explains not only the preservation of the ‘Hochterrasse’/Rodia fluvial gravels, but also how exceptional this preservation is within the Thessalian basin. At this point, it is fruitful to address another question: if landscape dynamics, disfavoring preservation of material throughout multiple climatic cycles, elucidate the scantiness of the Greek record in both quantitative and qualitative terms, how could we explain the richness of other circum-Mediterranean records, considering the similarities in climatic trends and overall geomorphic processes in the Mediterranean? Due to limited space here, I will only briefly outline how specific differences, mainly in topography and tectonic history, can explain the disparity between the records. To this end, I will use as examples the Iberian and Italian peninsulas.

Compared to the high relief of Greece, Iberia is characterized by a low relief with mean slopes of 7.1 degrees (Benito-Calvo *et al.* 2009). According to a morphometric classification (*ibid*), the most extensive class represents intermediate plateaus and plains, which occupy 23% of the Iberian surface. Coastal lands, valleys and plains of low altitude and low gradients (mean: 2.9°) occupy 15% (unit 1); the plains and valleys with gentle slopes (mean: 2.8°) cover 16.3% (unit 2), and hillsides and valley slopes with a mean 9.8° represent 11.4%. In other words, 42.7% of the peninsula comprises of low relief with low-to-medium gradient slopes (units 1 to 3), whilst the plateaus and plains of the interior (essentially: the Iberian Meseta) add another 23% of areas with very low topographic roughness and gentle slopes (mean: 2.7°); overall, the low-relief areas reach a total of 65% of the peninsula. Although the latter values are not straightforwardly comparable to those derived from the slope-map of Greece (Fig. 6.24 and Table 6.4), they give us a first-order appreciation of the differences in relief (and gradients) between the two peninsulas: as a general trend, the percentage of low relief areas in Iberia almost equals the percentage of

high relief areas in Greece. As described in section 3.3, most of the Lower Palaeolithic sites of Iberia are located in those low-relief/low-gradient terrains, with the majority of them situated on the high elevated flat surfaces of the ‘Iberian Meseta’, in the interior of the peninsula. The low relief of the Meseta was developed already before the Quaternary (Casas-Sainz and de Vicente 2009); hence, anthropogenic material was to be discarded (and potentially buried) on low-gradient terrains. The causes and timing of the uplift of the Meseta is debated, but a recent study (*ibid*) suggests that it probably had two main components: 1) Alpine compressional tectonics 2) a recent, Plio-Pleistocene stage of uplift. Most likely related to the latter (Plio-Pleistocene uplift) is a major transition affecting the Meseta: the plains and basins (*e.g.* the Duero, Ebro and Tagus basins), which were until that time endorheic (internally drained), were captured by the fluvial systems and changed to exorheic. The transition from endorheism to exorheism marks the onset of drainage reversal, river incision and hence dissection and erosion of the basins and plains. The precise timing of this transition is not resolved with regard to specific stages within the Quaternary and it probably differed regionally. Yet, strong incision observed in some basins (*e.g.* parts of the Duero) is described as occurring in ‘recent times’ (Casas-Sainz and de Vicente 2009). I would thus point out the possibility that well-preserved Lower Palaeolithic sites in Iberian basins and plains remained buried and protected from erosion for most of the Early and Middle Pleistocene, and were only recently (Late Pleistocene to the present) exhumed by river incision, the latter providing the necessary degree of archaeological visibility. An example of such a case can be given with respect to the sites near Orce.

The intramontane Guadix-Baza (G-B) basin is situated on a plateau with a mean elevation of 1000 m, now intensely dissected by the river network. A >600 m-thick sequence of fluvio-lacustrine sediments (>2500 m-thick in the centre near Baza) accumulated in the enclosed, endorheic depression of G-B (Scott *et al.* 2007). Activity along the Baza normal fault since *ca.* 8 Ma provided accommodation space for continuous sedimentation in the Baza sub-basin, which was formed in the hanging-wall of this fault (Alfaro *et al.* 2008). A large lake occupied the depocentre of the latter area, and the archaeological and

palaeontological sites (*e.g.* Barranco León, Fuente Nueva 3) are located at the margins of this palaeo-lake (Barsky *et al.* 2010: fig. 2). Alluvial fans on the borders of the basin were gradually connected with the central lake (Pérez-Peña *et al.* 2009). Besides the gently sloping fans, the fluvio-lacustrine sediments of Baza lie horizontally and the entire depression is described as an “essentially flat, elevated region” (Pérez-Peña *et al.* 2009, 206; Díaz-Hernández and Juliá 2006). The central Betic Cordillera, where the G-B basin is located, is currently subjected to regional uplift (Alfero *et al.* 2008), but the Pliocene-Pleistocene evolution of the basin was dominated by sedimentary processes largely undisturbed by significant tectonic events (Pérez-Peña *et al.* 2009). At a certain point, the former, endorheic drainage was captured by the Guadalquivir river system due to uplift (Díaz-Hernández and Juliá) and the drainage of the basin changed from endorheic to exorheic; from that point on, lacustrine and fluvial sedimentation ended and erosion predominated in the area (Alfaro *et al.* 2008; Pérez-Peña *et al.* 2009). While the exact age of this change is debated, the most recent study regards it as younger than *ca.* 43 ka (Pérez-Peña *et al.* 2009). Since the basin was captured by the Guadalquivir, the level of the sea, *i.e.* about 1000 m lower than the river’s level, became the base level of erosion; for the river to adjust its profile to the new conditions, it had to erode the poorly consolidated Neogene-Quaternary sedimentary fill and the incision wave propagated headward very rapidly, but its intensity decreased over time (*ibid.*, 214). Most of the erosion has since been concentrated in the Guadix sub-basin, because it is close to the capture point (Pérez-Peña *et al.* 2009). The Baza fault delayed the propagation of erosion into the Baza sub-basin, and this explains the large differences in erosion rates between the two sub-basins (*ibid.*).

In translating this picture into geoarchaeological terms, two points need to be stressed:

1. During the Early and Middle Pleistocene sedimentation was continuous and with high rates (~10 cm/ka; Scott *et al.* 2007). It largely consisted of fine-grained material and it essentially formed a flat-lying terrain. Hence, the most important prerequisites for a good preservation potential were in place: fine-grained material
2. Erosion started only late in the Late Pleistocene (after *ca.* 43 ka), it was probably vigorous in the beginning (*i.e.* upon capture of the drainage by the Guadalquivir) but it gradually slowed down. The incision/erosion wave affected mainly the Guadix area, whilst its propagation to Baza was buffered by the Baza fault⁶⁶. Encroachment of the drainage in Baza only served as to expose the Early and Middle Pleistocene sediments, instead of severely eroding them, as it is the case with the badlands directly adjacent to the S/SW of Orce (*cf.* Díaz-Hernández and Juliá 2006: fig. 1). Therefore, for the Orce sites, the most important requirement for today’s good archaeological visibility was there, too: erosion starting only late in the Pleistocene, stripping off uppermost sediments and exposing lower layers and associated artefacts without disturbing them.

The case of Italy is also instructive, because, in contrast to Iberia, its topography is much more similar to that of Greece, with alluvial plains and flatlands covering about ¼ of the peninsula (Mussi 2001). The majority of the Lower Palaeolithic sites are associated with the fluvial and/or lacustrine depositional settings of the Apenninic basins (see section 3.2). The Late Pliocene and Early-Middle Pleistocene of Italy are characterized by lacustrine environments of low relief in most intramontane depressions, which hosted swamps and floodplains of mainly fine-grained sediments (Bartolini 2003; Bartolini *et al.* 2003). These closed and semi-closed drainage systems were chiefly internally drained (endorheic), because the low relief prevented streams from eroding divides and capturing the drainage (Bartolini 2003). After the Middle Pleistocene, lacustrine sedimentation was significantly reduced, continuing only in a few basins that maintained internal drainage (Bartolini *et al.* 2003, 214). It is during the Middle and Late Pleistocene that a major rearrangement occurred in the depositional settings of the Apenninic depres-

66. In contrast to the wealth of well-preserved palaeontological and archaeological sites of Baza, the Guadix is almost devoid of sites; this would reinforce the ‘preservation argument’ advanced here.

sions: the fluvio-lacustrine environments changed to fluvial-alluvial sequences “in a regionally correlated phase of basin fill incision and drainage integration” (ibid). The change from internally-drained lacustrine systems to through-going fluvial networks is related to the uplift of the Apenninic chain and the creation of the necessary relief that provided the streams with the required energy to capture the drainages (ibid). As a result, the older (Early-Middle Pleistocene) fluvio-lacustrine units were being incised and eroded, and they are now overlain by units transitional from low-gradient lacustrine and fluvial environments to coarser deposits of alluvial fans. The uplift that occurred from the Middle Pleistocene onwards was time-transgressive and the drainage-change did not affect all basins, but, as a general pattern, it involved most of them (Bartolini *et al.* 2003). For those basins that were captured later in the Pleistocene (Late Pleistocene), we can envisage the low-gradient lacustrine palaeo-surfaces being covered and thus protected throughout the Early and Middle Pleistocene; as with the case of the Iberian example mentioned above, this would have offered better chances for associated archaeological material to attain a high degree of preservation and relatively good visibility after dissection and erosion due to uplift. This is exactly what happened at Isernia: human activity is recorded in low-energy, flat-lying lacustrine sediments that were subsequently covered by high-energy stream deposits, generated by a considerable increase in gradient due to the Middle Pleistocene tectonic movements (Mussi 2001, 24).

The examples from the Iberian and Italian peninsulas demonstrate that the disparity between the Lower Palaeolithic records of the latter areas with that of Greece can be explained by differences in topography and tectonic history. What emerges as a key-factor is *the timing of uplift and the intensity of erosion accompanying the inversion of basinal settings*. In rather ideal situations (*e.g.* Orce sites), Early and Middle Pleistocene sediments of low-gradient settings (*e.g.* lacustrine) are being protected by burial until the late Pleistocene; then, uplift signals the onset of dissection, erosion and exposure, but, in such cases, the exposed sediments are subjected to the erosional effects of ‘only’ one full glacial-interglacial cycle, and have therefore better chances to be preserved. I would argue that such an ‘advantageous

timing of uplift’ (Late Pleistocene) was rather exceptional for the lowlands of Greece; in contrast, most basins were affected by uplift already in the Early and Middle Pleistocene. This had important consequences in the tecto-sedimentary evolution of the depressions and the preservation potential for sediments and associated archaeological material. When uplift occurs in the Early Pleistocene, there is limited sedimentation in the uplifted area in the Middle Pleistocene, whilst already deposited (Early Pleistocene) sediments are subjected to dissection and erosion throughout multiple glacial-interglacial cycles from the Early Pleistocene to the present. Likewise, when uplift starts in the Middle Pleistocene, (Middle and) Late Pleistocene sedimentation is reduced in the uplifting block, hence any Middle Pleistocene sediments have very low chances of being covered and protected -instead, soon after their deposition they are subjected to the erosional effects of stream dissection, throughout more-than-one climatic cycles; any Early Pleistocene sediments (pre-dating the uplift) have essentially the same fate, too. In section 6.3, I examined in more detail the consequences of this timing of uplift with respect to the Megara basin and the Gulf of Corinth, for which no Lower or Middle Palaeolithic evidence has been reported so far. The case of the Thessalian basin, where the site of Rodia is situated, was also discussed in this respect, because parts of it were uplifted during the Late Pliocene-Early Pleistocene and then again in the Middle Pleistocene (section 4.6.2, 4.6.5 and 6.3); as a result of this uplift, Early and Middle Pleistocene sediments in Thessaly (the greatest lowland area of Greece) occupy today a meager *ca.* 0.8% of the basin. Similar to the endorheism-exorheism transition discussed for the Iberian and Italian basins, the Thessalian drainage changed from an internally-drained Pliocene lake to a through-going fluvial network (the Pineios river drainage); in contrast to the basins of the Iberian Meseta or the Apennines, this transition occurred in Thessaly in the Early Pleistocene, due to uplift related with the first major tectonic phase affecting the region. Earlier, I stressed how the site of Rodia exemplifies most of the major archaeological issues of the Lower Palaeolithic record of Greece (notably, the dating problems). In light of the discussion above, I would add now that Thessaly and Rodia exemplify also the limited geological opportunities for the preservation and/or visibility of early Pleistocene sediments in

Greek basinal settings, as well as the reasons accounting for this picture (a disadvantageous ‘timing of uplift’). In contrast, the small basin of Kokkinopilos appears to have been inverted relatively recently and the intensity of erosion has accelerated also in geologically very recent times; if the soils of Kokkinopilos were not acidic but alkaline, favoring the preservation of fossils, this site could have been a miniature of the situation seen at Orce.

To sum up, in the model that I suggest as central for explaining the scarcity of the Lower Palaeolithic record of Greece -as compared to those of other Mediterranean regions (*e.g.* Spain, Italy)- *basin inversions and drainage diversions occurred already in the early rather than the late Pleistocene*. While most of the Iberian and Italian basins were experiencing a period of relative quiescence during the Early Pleistocene, (parts of) the Greek basins changed from ‘sediment-receiving’ to ‘sediment-producing’ areas, in which erosion predominated over deposition. In turn, this can be explained by the fact that *the last tectonic paroxysm in Greece seems to have begun in the early and middle Pleistocene*. In section 6.3 it was pointed out that in the Early and early-middle Pleistocene, a compressional regime invaded the broader Aegean region, separating the extensional regimes that prevailed before and after that time-span. During this intense compressional phase (*ca.* 1.0–0.7 Ma), the entire Hellenic arc was uplifted and convergence rates increased at its outer circumference from 1 to 3 cm/year (Schattner 2010, 545). In the early-middle Pleistocene (locally better resolved as in the Middle Pleistocene), a reorganization of stress trajectories occurred in the southern and northern Aegean, and in the north (Florina-Vegorit-Ptolemais graben) as well as central mainland Greece (Thessaly); a third phase of opening affected the Gulf of Corinth; whilst some basins and coastal areas in Peloponnesus were being uplifted. As a whole, these developments are probably related to *a major tectonic event that occurred across the entire eastern Mediterranean during the early-to-middle Pleistocene*, manifested by a series of synchronous structural deformations that accentuated the topography (Schattner and Lazar 2009; Schattner 2010).

7.4 PROSPECTING THE FUTURE OF LOWER PALAEOLITHIC INVESTIGATIONS IN GREECE

Asking for more -and, ideally, radiometric- dates to bracket the Greek Lower Palaeolithic would sound as a cliché, if not because a more precise dating is needed for the regional Middle and Upper Palaeolithic records as well. Yet, the examination of the Early and Middle Pleistocene archaeological evidence from Greece as a whole (chapter 4), along with the zoomed-in fieldwork-based investigations of specific case-studies (Thessaly, Epirus; Aliakmon and Zakynthos survey projects), altogether demonstrated that the necessity for building regional chronostratigraphic frameworks is currently the number one priority. Contributing in this direction, sediment samples that I collected from Kokkinopilos have been submitted to the Netherlands Center for Luminescence (results pending). In one of my revisits at Rodia, together with R. Caputo (Professor of Structural Geology, University of Ferrara), we were able to assess that the fluvial gravels at FS 30 are probably about a million years older than previously thought. On the other hand, my own experience at, for instance, the ‘red-bed sites’ of Epirus or Rodia in Thessaly, suggests that even the very same assessment of ‘what to date’ is by no means an easy task: considering the erosional and/or reworked character of most (Early/Middle Pleistocene) preserved landforms and land-surfaces, great care must be taken not only when targeting sampling points, but also in interpreting the dated event (be that depositional or, even worse, erosional). Paleosol chronosequences have already proved to be significantly helpful in relative dating, providing *post* or *ante quem* estimates for artefacts resting on or buried within paleosols. Paleosol stratigraphy has been successfully integrated in Palaeolithic investigations in Epirus, Thessaly, Macedonia and Peloponnesus, but the complex soil sequences and depositional histories of the Greek landscapes call for attention when using pedostratigraphy for dating purposes. Furthermore, we still lack a confirmed model to explain the incorporation of artefacts inside paleosol horizons (*cf.* van Andel 1998), although some explanatory suggestions have already been presented with regard to the paleosols formed on redeposited *terra rossa* (Runnels and van Andel 2003); these need to be further elaborated

and tested in other depositional contexts, preferably along with the application of micromorphology. Biochronology can also be of much help in relative dating and in calibrating other dating techniques, especially when considering the constraints in absolute dating methods applied to the Early and Middle Pleistocene. Unfortunately, areas as rich in Palaeolithic finds as Epirus are blanketed with acidic soils, offering a very low potential for the preservation of faunal and hominin fossils; regions of southern Greece or Macedonia are most promising in that respect.

In order to establish a solid chronostratigraphic framework, we need not only more dating assays, but also more stratified material. Although this is an obvious prerequisite, it is not always a straightforward objective in research designs, mainly due to a reality of ‘low returns’ attached to this aim. In discussing the results of the Aliakmon Survey Project, I emphasized that the search for *in situ* material was the proper way to pursue the project’s goals, even if -in retrospect- this choice did not yield the desired outcome. As is obvious from the assessment of the Greek data-set, the crux of the problem in deciding over the existence of a Greek Lower Palaeolithic lies principally in the shortage of stratified remains. Thus far, there are no reports of horizontally extensive Lower Palaeolithic surface scatters (as in the case of, for instance, the Iberian Meseta), and my research indicates that such instances will hardly ever be found: it is not so much a matter of research intensity, it is more an issue of geomorphic controls. If exposed surfaces with ‘veils of handaxes’ are chiefly ‘wishful thinking’ for Greece, a great number of new surface finds would be needed if we are to say anything more than echoing the results presented here; at best, surface material from new areas would extend the mapped distribution of Lower Palaeolithic human presence –provided that the material is indeed able to do so (e.g. on the grounds of typo-technological criteria combined with geomorphological observations, if the collection is not mixed with younger material, etc). In contrast, *in situ* remains may acquire an importance much wider than that of mere data points in distribution maps. For the rudimentary status of the Greek Lower Palaeolithic, these will be the primary building blocks for a reference framework towards a regional culture-stratigraphic sequencing of surface

collections, save that the excavation of *in situ* material is the only means in unraveling hominin behavioral traits. This is not to undermine the value of non-stratified artefacts; rather, it is to emphasize that only with such reference-frameworks can surface material be used in a most fruitful manner. Far from being pessimistic, one is forced to expect that surface finds will continue to dominate the Greek Lower Palaeolithic collections of the future, at least in as much as they dominate the rest of the circum-Mediterranean records.

Where should we look for this highly-prized, potentially undisturbed and preferably stratified Lower Palaeolithic material? As has been repeatedly underlined throughout this book, low-gradient palaeosurfaces in basinal settings provide the best potential for a high quality of preservation; when inverted due to uplift, they may also offer the other main prerequisite for successful recovery: exposure, and hence archaeological visibility. The site of Kokkinopilos was emphasized (section 4.5.5) as providing such a ‘window of opportunity’, which combines both aforementioned parameters (preservation and visibility). Kokkinopilos was a closed depression (a *polje*), in which *terra rossa* has been redeposited in the low-gradient, low-energy depositional environment of an ephemeral lake; fault activity and uplift changed the drainage from endorheic to exorheic, initiating dissection, gully formation and exposure of long stratigraphic sections. ‘Absolute’ dating of this transition is lacking, but the intense erosion creating the badland morphology is most probably a recent phenomenon (Late Pleistocene but, mostly, Holocene). However, in contrast to what happened in e.g. the Guadix-Baza basin, erosion has not slowed down at Kokkinopilos; rather, it has been accelerated, most likely in very recent times. As a consequence, Kokkinopilos exemplifies also the latent drawbacks associated with such drainage transitions: excavating the badlands of Kokkinopilos will be a very difficult exercise, during which much attention will have to be paid to distinguishing between gully-reworked and non-reworked parts of the site⁶⁷. Relatively better opportunities for

67. Such a recent but intense erosional history indicates how the pace of geomorphic disturbance may be set by sub-millennial, even decadal-scale climatic fluctuations, as well as

subsurface investigations are offered by the current morphology and sedimentary preservation of another red-bed site of Epirus, namely Morphi. Lower Palaeolithic artefacts have not been reported yet from Morphi, but the site has a strong Middle Palaeolithic component and a thick tephra deposit to serve as an invaluable stratigraphic marker. The tephra at Morphi dates to *ca.* 374 ka and underlies a 12 m-thick red-bed zone, which is marked by paleosol horizons and is similar to zone B of Kokkinopilos (*i.e.* the zone where the Micoquian handaxe was found). Should artefacts occur immediately above the tephra (as my own, preliminary observations indicate), their typo-technological analysis could shed light to technological variability within this enigmatic time-frame (*ca.* 350-150 ka), potentially assisting in sketching for the first time a regional culture-stratigraphic ‘boundary’ between the Lower and the Middle Palaeolithic. Moreover, I would expect the red-bed sequence to continue also under the tephra; although the site is largely covered by recent (Holocene) alluvial deposits of unknown thickness, trial-trenches at selected locations could test the possibility of finding artefacts stratigraphically below the tephra.

The basin of Megalopolis in Peloponnesus would be another primary target for future research. Here, there is an essentially continuous Early and Middle Pleistocene lacustrine sequence of fine-grained sediments, accumulated in an internally-drained lake; at some point, most probably in the late Pleistocene, the drainage was captured by the Alfeios river, which eventually emptied the palaeo-lake. Therefore, Megalopolis experienced an advantageous –for today’s investigations– timing of drainage diversion, as in the case of the Spanish and Italian examples mentioned earlier. Flint artefacts have already been documented from locations that would have been at the margins of this lake (see section 4.7.2). Moreover, a hominin tooth that was found there in the 1960’s was reported as associated with a Biharian fauna (Sickenberg 1975) and is currently being re-studied (Harvati *et al.* in prep.). In this light, Megalopolis can be re-

garded as the most promising candidate for the recovery of an ‘Isernia-type’, primary-context Lower Palaeolithic site in Greece. Nonetheless, the exploitation of the lignite seams of the basin in opencast mines poses immense problems to the realization of archaeological excavations, as large parts of the basin have been significantly disturbed and reworked due to the quarrying operations –let alone the administrative issues that any research team would have to face. On the positive side, many sectors of the basin’s circumference have not been affected by quarrying. I would expect traces of hominin activity to be found at the margins of the palaeo-lake and this is where any surface or subsurface investigations should start with. Although Megalopolis has been extensively studied by geologists and palaeontologists, a great deal of original work is needed before and/or upon launching an archaeological research. Geomorphological mapping along with a small-scale dating project would be some of the first steps towards pinpointing locales for further investigation. On the basis of my personal observations and as a general strategy, I would also suggest the targeting of natural outcrops of lacustrine/fluvio-lacustrine deposits of the Early-Middle Pleistocene that were later exposed by streams, since the establishment of the Alfeios river network. In future investigations, priority could be given to deposits of the Choremi Formation and particularly its fossiliferous Marathousa Member, from which the hominin tooth is considered to be derived, but also to the early Pleistocene Apiditsa Formation. Overall, exposed sediments of the aforementioned formations should first be sought in the western part of the basin and preferably at locations that would have been at the margins of the palaeo-lake.

Not far from Petralona cave, the basin of Mygdonia in Macedonia (section 4.3.2) offers a depositional setting similar to that of Megalopolis, with lacustrine and fluvio-lacustrine sequences that extend back to the Early Pleistocene. A rich Pleistocene fauna has been discovered here, whilst unpublished results from an archaeological survey project note the presence of quartz artefacts that have been preliminary attributed to the ‘Early Palaeolithic’. Moreover, the saber-tooth *Megantereon whitei*, possibly related to hominin arrival(s) in Europe and found also in Dmanisi (Georgia) and Venta Micena (Orce, Spain), is in-

Holocene anthropogenic influences; as a result, the infill of Kokkinopilos will not survive not even half a glacial-interglacial cycle.

cluded among the fauna of the important Early Pleistocene palaeontological locality of Apollonia. Examining outcrops of the Gerakarou and Platanochori Formations, with which many Villafranchian localities are associated (Koufos *et al.* 1995), would be a starting point for investigations in this basin. Notably, Mygdonia includes also Plio-Pleistocene volcanics (Mendrinou *et al.* 2010), which can be used not only as stratigraphic markers for regional correlations, but also for dating purposes.

The examples of Megalopolis and Mygdonia could be seen as representing some of the most prominent cases for recovering *in situ* Lower Palaeolithic material from fine-grained, lacustrine primary contexts. They also refer to depressions that are not *terra incognita* in terms of geological and geomorphological studies, archaeological investigations or palaeontological findings – a fact that adds extra advantages for any further research. In the same line, other basinal settings that can be pointed out would be, for instance, parts of the Florina-Ptolemais-Kozani basin complex, in which lakes that formed in the middle Miocene might have persisted into the Pleistocene, and from which Early Pleistocene proboscidean fossils have been reported (*e.g.* Doukas and Athanassiou 2003). The exact timing in the Pleistocene, when this basinal complex was fractured into the Florina, Ptolemais and Kozani (Servia) sub-basins is not well-resolved, but, if it occurred in the Late Pleistocene, the uplifted blocks of the sub-basins may prove to offer good visibility due to stream dissection. The depressions of eastern Macedonia and Thrace would have hosted highly productive habitats, conditioned by the combined and/or alternating existence of lakes, marshes, lagoons and shallow beaches (Psilovikos and Syrides 1984). Moreover, those complex and diverse drainage systems would have served as natural routes for animal and hominin movements, connecting the regions of the Near East with the Balkans and Europe⁶⁸. However, these areas have been affected by marine transgressions and fluvial sedimentation, the latter resulting in the accumulation of 10- to 100-m-thick deposits overlying the Early and Middle

Pleistocene sediments. For instance, large parts of the Serres-Drama basin were covered by lakes (Echinos-Philippi), which were later filled with sediments debouched by Strymonas River (*ibid.*, 111). As a consequence, preservation potential may have been high here, but archaeological visibility is overall low at present. Nonetheless, the documentation of palaeontological localities (*e.g.* Tsoukala 1991; Athanassiou and Kostopoulos 2001; Doukas and Athanassiou 2003) indicates that there still exist possibilities for investigating out-cropping deposits.

The rest of the remaining key basinal settings of Greece are characterized by environments where either limnic deposits occur chiefly intermixed with fluvio-terrestrial sediments or where a preponderance of basically fluvial and/or alluvial/torrential deposits is documented. As a general trend, fluvial fines (*e.g.* overbank loams) are commonly under-represented in those sequences, occurring mainly in vertically restricted facies. Alternatively, wherever preserved and exposed, such fine-grained layers can serve as ‘marker beds’ that are easily visible and can be followed laterally. Nonetheless, the potential for recovering artefacts from primary contexts is reduced here, compared to the possibilities provided by former lake-settings, because of the highly dynamic environments of river systems and their ability to repeatedly rework older deposits (*cf.* section 6.2). The fluvial settings of Thessaly and Western Macedonia (Aliakmon basin) have already been discussed in some detail. Here, it is sufficient to emphasize two main points: (1) the new observations on the stratigraphy at Rodia (Thessaly), presented in this study, can be regarded as stimulating points of departure for further investigations: a lot of uncertainties may remain, but now we have at least some rough, new indications on the age of the deposits, and we can narrow-down the focus of investigations, *e.g.* in spatial terms (Middle Thessalian Hills and the area around the Rodia Narrows) or in terms of the lithic material to be targeted (quartz); (2) similarly, the Aliakmonas Survey Project paved the way for further research: apart from the new lithic and fossil collections, large areas were mapped and the first steps towards resolving the terrace-staircase system have been made, whilst radiometric dates are pending. In short, the results of this research and of previous projects may not be as impressive as originally

68. To put it in an archaeological scenery, they would connect the cave of Petralona with that of Yarımburgaz (which were almost contemporaneously in use).

hoped, but they are encouraging enough to suggest that there is still a lot to be researched in both of these two major river basins of Greece. Other important drainage networks remain virtually unexplored with regard to systematic investigations of Early and Middle Pleistocene deposits. Included in those are the greatest parts of the Axios river-Thessaloniki basin in northern Greece and those of Pyrgos-Kyllini basins in Peloponnesus; early Pleistocene fauna has been recorded in both of them (*e.g.* in the lower Axios valley for the former, and at Pyrgos and Kaifas for the latter; van der Meulen and van Kolfschoten 1986; Tsoukala and Melentis 1994; Koufos 2001; Doukas and Athanassiou 2003). Smaller-scale river basins, such as those of the Kalamata, the Kardamyli and the Oitylo in Peloponnesus, are by no means negligible, although they are mostly filled with conglomerates and sandstones deposited in alluvial fan and deltaic environments (*e.g.* Zelilidis and Kontopoulos 1999). Along the southern margin of the Gulf of Corinth (section 6.3), Early and Middle Pleistocene fan-deltas are exposed in outcrops of km-scale (both vertically and horizontally), which remain also unexplored; high-energy conglomeratic units predominate here, but lacustrine-lagoonal facies and floodplain fines are also interbedded. High Early to Middle Pleistocene sedimentation rates and a ‘good timing’ in the uplift of the depositional sequences (late Middle to Late Pleistocene until present), resulting in fan abandonment and stream dissection, place this case among the aforementioned group of inverted basinal settings; but, although there is a lot of potential for recovering *in situ* remains, there are equally lot of hindrances, most notably the fact that these are in essence massively bedded, unreachably high profiles of dominantly coarse-grained calibre.

Last but not least, caves and rockshelters should not be overlooked, despite the fact that cave use is an overall marginal and late phenomenon in the entire European Lower Palaeolithic record. Caves are indispensable sediment-traps that can potentially provide high-resolution geo-archaeological archives, and this is one of the reasons why they have so far been the dominant target in systematic investigations on the Palaeolithic of Greece. Certainly, there still remains a significant number of caves and rockshelters to be examined, while in some of those which have al-

ready been or are still being investigated, the excavations did not or have not yet reached the bedrock.

Section 6.4 highlighted the potential and the constraints for both subaerial and submarine research in the Aegean and Ionian islands. Similar to the above-suggested directions for fieldwork in mainland Greece, insular investigations could start with targeting basinal settings, especially those of islands with already documented palaeontological and/or archaeological findings (*e.g.* Crete, Rhodes, Mytilene, Milos). Earlier above (7.2), I stressed that the ‘best half’ of the Greek record (*i.e.* the once-emerged Aegean/Ionian landmasses) is now submerged. Yet, this could also be translated to a prediction that the likelihood of recovering here an Early/Middle Pleistocene primary-context site could be reversely related to the quality potential of this site: the surprises that the Aegean region can yield may be of such an exceptional character that we are still unable to foresee.

7.5 SUGGESTED RESEARCH SUBJECTS FOR FUTURE EXAMINATIONS

What we can indeed already anticipate is that the improvement of the Greek Lower Palaeolithic data-set is going to be a painstaking process: conditioned by a highly dynamic Quaternary landscape, the geological opportunities for the preservation of the Early and Middle Pleistocene archaeological archive are limited, and -as a general assessment- they seem to be significantly more limited than that of, for instance, the Iberian or the Italian peninsulas. This is not to undermine the potential for future discoveries in Greece: the more we realize and apprehend the effects of geomorphic biases, the more we armor our methodologies with analytical tools capable of unveiling those biases and hence locating new sites to unearth. It is in this direction that the research presented here aspired to contribute, and, as this direction follows the paths of earth-science disciplinary fields, my study was structured along a geoarchaeological axis. Other parallel and/or convergent lines of analysis towards examining the present status and future prospects of the Greek Lower Palaeolithic record could not be included here due to space limitations. The following issues could be considered as points of departure for such alternative (but also, complementing) lines of analysis:

1. A distinct biogeographical pattern appears to emerge with regard to glacial floral populations (and their range contractions/expansions) between eastern and western Greece (*cf.* section 6.2). How would this pattern be differentiated during interglacials, what was its contribution to the erosion/preservation potential and how is it associated with the apparent abundance of Palaeolithic sites in western Greece as compared to the eastern parts of the peninsula? In which ways could it have affected animal (and human) population distributions?
2. Considering the latest palaeogeographical reconstruction of the Pleistocene Aegean and Ionian Seas, it could be argued that Greece functioned not only as a refugium, but also as a 'transit area' (instead of a 'cul de sac') for animal and human movements in an east-to-west biogeographical and/or climatic transect. At least for the middle Pleistocene, "massive immigrations of new species from Asia" have been assumed (Mussi 2001, 19), and a rapid increase in faunal diversity observed in all three Mediterranean peninsulas (Greece, Italy, Iberia) is thought to be related to a progressive diffusion of taxa from Eastern and Central Europe (Kostopoulos *et al.* 2007). Let us recall here that South-East Europe and the area around the Black Sea is the region where "the humid faunas of Europe and Northern Asia intergrade with the faunas that lived in the arid area that extends from N. Africa to Central Asia" (van der Made and Mateos 2010). In extent, as soon as new hominin fossils are discovered in Greece, it will be of no great surprise if they also prove to belong to species originating from areas to the east of Greece. Overall, faunal and hominin biogeographical patterns and natural routes for large-scale movements are still under-studied in the broader Aegean region, much more with regard to east-west trending events.
3. Climatic fluctuations, intense tectonic activity and a complex topographic configuration would have increased environmental heterogeneity of Pleistocene Greece to levels probably even higher than those at present. Hominin forms within the hypodigm of *H. erectus* (*s.l.*) are assumed to have been generalists in their diet and to have used an unspecialized technological tool-kit; by all accounts, and following similar suggestions put

forth for the Italian record (*cf.* Mussi 2001), it is relatively safe to assume that early hominins would have been attracted by the mosaic habitats of Greece. In fact, it has been argued that *H. erectus* was a 'weed' taxon that profited from habitat fragmentation and ecosystem instability, being adapted for environmental and long-term habitat disturbance (Cachel and Harris 1998). Earlier in this study, the same parameters (climate oscillations and marked seasonality, ever-present tectonism and a 'broken-up' topography) were called upon to explain landscape instability and the limited preservation potential of the geoarchaeological archive. In other words, the same factors and processes that would have created conditions of landscape disturbance, allowing weed-like taxa to "thrive in disrupted environments" (*ibid.*, 119), are the ones also responsible for constraining the potential for hominin cultural and fossil remains to be preserved. As a working hypothesis for future research to test, I suggest here that there may be an inverse relationship between the degree of geo-climatic mosaicism and preservation potential. The approach advanced here sketched out possible means of assessing preservation potential for low-resolution data-sets in a large-scale spatio-temporal perspective; for records of higher resolution and for smaller scales of analysis, a more fine-grained modeling can be achieved. The 'degree of geo-climatic mosaicism' can be modeled by use of applied analytical tools, such as that of geodiversity⁶⁹. Geodiversity assesses "the constituent elements within the physical environment that participate in the richness of biotopes, ecosystems or landscapes" (Reynard and Coratza 2007, 138); with a combination of morphometric, geological and morphoclimatic maps, and with the use of metric indices and spatial statistical analysis, the study of geodiversity allows researchers to quantify, describe and compare different land-

69. Geodiversity is defined as "the natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes. Geodiversity includes evidence of the past life, ecosystems and environments in the history of the earth as well as a range of atmospheric, hydrological and biological processes currently acting on rocks, landforms and soils" (Zwolski 2004)

scapes, which can be either coeval in separate locations or throughout time (Benito-Calvo *et al.* 2009); as such, it provides “an objective and useful tool to understand the singularity and geocomplexity of landscapes” (ibid, 1433).

So far, the early colonization of Europe/Eurasia has been approached by focusing on a combination of various parameters, such as environmental constraints and climatic variability; behavioral capacities of the hominin agents (*e.g.* technological repertoires, hunting *vs.* scavenging, use of fire, etc); life history features and social organization; biogeographical and zooarchaeological proxies (*e.g.* mammal expansions, contractions and renewals, such as that of the carnivore guild); as well as a whole array of lines of evidence from multi- and inter-disciplinary domains, most of which are included in Life Sciences. This study elaborated on a hitherto largely neglected aspect of a Eurasian Early-Middle Pleistocene record: the biasing effects of geomorphic processes. The role of landscape processes in biasing archaeological records is commonly approached within the small-scale of individual sites. Choosing the scanty record of Greece as a case-study, this examination set forth to explore the first steps towards integrating geomorphic biases into approaches that consider wider temporal and spatial scales. If we are to ‘get the pattern right’ in *identifying* spatio-temporal models of

human presence/absence (Roebroeks 2006), then we need to develop analytical tools which will shed light on what geomorphic biases conceal or have already erased. Besides research biases, it is time to consider other possibilities when *explaining* the identified patterns: for example, the marked difference between the early Palaeolithic archaeological record of Greece and that of Italy or Spain, was suggested here to be more an artefact of Earth-Sciences-related matters (geomorphic biasing), than a reality explained in terms of Life-Sciences-related trajectories (*e.g.* hominin preferences). It can be argued that analogous examinations are needed before assessing ‘first’ and ‘last appearance dates’ of hominins in regions such as those of Asia, for which -likewise Greece- very little is known (*cf.* Dennell and Roebroeks 2005). Similarly, the ‘500 m. altitudinal threshold’ that has recently been proposed as one of the decisive criteria of the Lower-to-Middle Palaeolithic transition (Hopkinson 2007; *cf.* section 2.2 and Mussi 2001), may in fact be -according to the results presented here- a geomorphological threshold reflecting geomorphic biases, rather than hominin behavioral constraints: at least for landscapes like those of Greece, the 500/600 m contour defines the upland-lowland boundary (*cf.* Macklin *et al.* 1995), as well as the boundary between ‘areas of erosion’ and ‘areas of sedimentation’ in river basins (*cf.* Pinet and Souriau 1988).

Epilogue

The results of this study have specific implications for the reading of the Early-Middle Pleistocene archaeological record of Greece and the prospects for its enrichment. They can also be seen as having wider implications for the methodology and practice of Quaternary Geoarchaeology in highly dynamic landscapes of south/south-eastern Europe –if not in even broader spatial scales.

The re-evaluation of the Greek testimony demonstrated the lack of archaeological assemblages that can be attributed to the Lower Palaeolithic on secure chronostratigraphic grounds. As attested by the palaeoanthropological record the Greek Peninsula was inhabited as early as the Middle Pleistocene, but we cannot assess whether the hominins represented by the fossils of Petralona and Megalopolis were the makers of what is conventionally defined as the material culture of the Lower Palaeolithic, even though such a hypothesis is most likely. Nevertheless, the human remains and artefactual evidence of the Middle Pleistocene together provide strong indications for a hominin presence in Greece during the Lower Palaeolithic period. The record is poor, ill-dated and essentially lacking a solid anchor on contextual (stratigraphic) evidence, but its ever-growing data-set must be considered as a signal that is highly promising for future discoveries.

This fragmented status of the record was interpreted here as the consequence of limited geological opportunities for the preservation and archaeological visibility of human vestiges from the Early and Middle Pleistocene. High relief in a tectonically active setting, combined with the small aerial extent of preserved Early and Middle Pleistocene deposits and the inundation of formerly-emerged landmasses, have altogether resulted in a very small portion of the record surviving up to the present. As pessimistic as this conclusion may appear to be at first sight, it

has two significant implications for future research in the Greek Peninsula, as well as with regard to the role of Greece in the investigation of the earliest occupation of Europe. Firstly, it does not contradict, but instead it even supports the expectations for the prospects of Greece in contributing to this subject: in all probability, the scarcity of Early-Middle Pleistocene archaeological evidence from Greece should be interpreted as the result of the biasing and destructive effects of Quaternary geomorphic processes and *not as a real absence of hominins*. Greece has provided fundamental archaeological and palaeoanthropological contributions with regard to the earliest agriculturalists in the Holocene, the late Neanderthals and the Middle-Upper Palaeolithic transition in the Late Pleistocene (*e.g.* the sites of Lakonis and Kleisoura), and the biological developments of the Middle Pleistocene (*e.g.* the sites of Petralona, Megalopolis and perhaps Apidima as well). It has also yielded a rich record of Neogene terrestrial primates (cercopithecids and hominoids; *e.g.* Koufos 2009), including key representatives of large-bodied hominids/hominines, such as *Ouranopithecus*, which has been interpreted as a direct link between Miocene apes and australopithecines (*e.g.* Koufos and de Bonis 2004); in fact, it was these sort of discoveries in the 1970's, from Greece (*e.g.* *Dryopithecus*) and Hungary, which repositioned Europe as the possible source of later hominines that dispersed into Africa in the late Miocene (Begun 2009). Hence, Greece occupies an important biogeographical position and has contributed significant evidence from the Miocene up to the Holocene, and the only substantial gap in this time-span regards the Early Pleistocene. It is hard to explain this gap in terms of unfavourable geoclimatic, palaeogeographic or ecological conditions; instead, my study indicates that, most likely, geomorphic biases are to be held responsible for it. After all, the fossil assemblages from two of the richest early-middle Pleistocene palaeontological localities of the region,

namely Petralona and Megalopolis, include also hominin remains.

In short, from the perspective of palaeontology, biogeography and palaeoecology there are still valid reasons to expect humans to have inhabited Greece as early as the Early Pleistocene. From a geoarchaeological perspective we have reasons to suggest that, wherever landscape processes allowed for a sufficient degree of preservation and visibility, archaeological and palaeoanthropological material *is indeed being found*. However, a second major result of the geoarchaeological explanation is that we need to significantly improve and revise our theoretical and methodological toolkits if we are to locate this early material *in stratified positions*. As already underlined, future research should focus on discovering stratified remains in order to assess their age and develop regional chronostratigraphic frameworks. To this end, fieldwork methodology needs to be adjusted accordingly: for instance, surveying land-surfaces with the traditional practice of field-walkers aligned every five or ten meters does not serve this priority adequately.

Apart from the issue of *how* to look for early Palaeolithic material, there is also the question of *where* to search for it. The geoarchaeological approach advanced in this study provided directions in answering this latter query, too. The approach was elaborated on the landscape-scale, it assessed preservation potential in conjunction with archaeological visibility and it emphasized topographic configuration and tectonic history as the two main factors that explain the inferior status of the Lower Palaeolithic record of Greece as compared to other Mediterranean records, notably those of the Iberian and Italian Peninsulas. This perspective had primarily an explanatory character, yet it was also used heuristically as a predictive tool: well-preserved and archaeologically visible Lower Palaeolithic sites are likely to occur in basin settings, which retained their role as ‘sediment receivers’ for most of the Early and Middle Pleistocene and were inverted into positive topographic features (‘sediment producers’) during the Late Pleistocene; in this framework, uplift, basin inversion and drainage diversion may or may not be associated with a transition from endorheism to exorheism in the local drainage system. For Greece, the basins of Megalopolis and Mygdonia

were pointed out as examples that most probably meet these criteria and offer themselves as the best candidates for yielding sites with hominin remains in primary contexts. Similar suggestions could be proposed for other Mediterranean regions with tectonically active settings, especially in the eastern Mediterranean. In this vein, the strength of the assessment on the association between archaeological preservation/visibility and the timing of basin inversions lies principally in its potential to be modeled, so as to assist in interpreting or predicting site distributions in the landscape-scale.

The most dramatic expression of the biasing effects of geomorphic processes relates to the periodic submergence of the Aegean: this has considerable implications with regard to how much of the Greek record has vanished and how important evidence the surviving part of it could yield in the future. Up till the present, the picture of a ‘continental Aegean’ was hardly conceivable by the palaeoanthropologists and archaeologists working in the region. The new reconstruction of the Aegean and Ionian palaeogeography (Lykousis 2009) and its archaeological implications discussed in this thesis will undoubtedly stimulate new research projects on the Palaeolithic occupation of the Aegean region. In light of this newly-acquired knowledge, the latter area now carries the potential for yielding evidence of profound significance for the understanding of behavioral developments, environmental tolerances and ecological preferences of early hominins. The recent finds from the islands of Milos and Gavdos (Chelidonio 2001; Kopaka and Matzanas 2009) can be seen as already prefacing such high prospects, while the evidence from Crete and the possibility that it attests to Lower Palaeolithic seafaring (Strasser *et al.* 2010) has already stirred up intriguing discussions. To my eyes, what is most exciting when prospecting the (Lower) Palaeolithic of the Aegean is its potentially central role in large-scale biogeographical patterns for hominins and other large mammals: if the Levant and western Turkey were “core areas [...] where hominin residence was almost always possible” (Dennell 2009, 233), the Aegean was certainly not peripheral. Instead, especially during the times of its full ‘continental emergence’, the Aegean provided direct connections between mainland Greece (and hence also northern Balkans) with Southwest Asia via Asia Minor. Thus, it is now

difficult to assume that the Greek Peninsula might have been a ‘cul de sac’ for faunal exchanges and movements (including hominins); this is in contrast to the Iberian and Italian peninsulas, which were always isolated from their surroundings in the longitudinal axis. It is in this latter axis that the Aegean may prove to be biogeographically important, perhaps as a true ‘melting pot’ for faunal and hominin interactions. Taking into account that the ‘Out of Asia’ palaeoanthropological scenario finds ever-increasing support from various lines of analyses (Dennell *et al.* 2010), the role of the broader Aegean region needs to be reconsidered: it is highly probable that it constituted not only an important refugium and ‘source area’ for (re-)colonizations, but also an integral part of *east-to-west (and vice versa) dispersal routes within West Eurasia*.

Even if not in numbers as great as we would wish for, Lower Palaeolithic sites of immense importance are yet to be discovered in the Greek Peninsula and the wider Aegean region. It is to this direction that the research presented here ultimately aspired to contribute. To this end, the examination had to be unfolded in three sequential steps: the first step was to *identify* the current status of the Lower Palaeolithic archaeological record of Greece; the second was to *explain* this status by use of a geoarchaeological and geomorphological perspective; while the aim of the third and last step was to *put in prospect* the enrichment of that record. It is now up to future research to make the ‘fourth step’ and start recovering Lower Palaeolithic sites, thereby placing Greece in the map of early Pleistocene human geography.

References

- Abbazzi, L., Fanfani, F., Ferretti, M.P. and Rook, L. 2000. New human remains of archaic *Homo sapiens* and Lower Palaeolithic industries from Visogliano (Duino Aurisina, Trieste, Italy). *Journal of Archaeological Science* 27, 1173-86
- Adam, E. 1998. Kokkinopilos. *Archaeologiko Deltio* 53 (part B, 2: Chronicles). Athens (2004) (in Greek)
- Agustí, J., Blain, H.-A., Cuenca-Bescós, G. and Bailon, S. 2009. Climate forcing of the first hominid dispersal in Western Europe. *Journal of Human Evolution* 57, 815-21
- Agustí, J., Blain, H.-A., Furió, M., De Marfá, R. and Santos-Cubedo, A. 2010. The early Pleistocene small vertebrate succession from the Orce region (Guadix-Baza Basin, SE Spain) and its bearing on the first human occupation of Europe. *Quaternary International* 223-224, 162-9
- Agustí, J., Oms, O. and Parés, J.M. 1999. Calibration of the Early-Middle Pleistocene transition in the continental beds of the Guadix-Baza Basin (SE Spain). *Quaternary Science Reviews* 18, 1409-17
- Agustí, J., Oms, O. and Parés, J.M. 2007. Biostratigraphy, paleomagnetism and geology of the Orce ravine (Southern Spain). Comment on the paper by Gibert *et al.* (2006). *Quaternary Science Reviews* 26, 568-72
- Ahnert, F. 1970. Functional relationship between denudation, relief and uplift in large mid-latitude drainage basins. *American Journal of Science* 268, 243-63
- Aiello, L.C. and Dunbar, R.I.M. 1993. Neocortex size, group size, and the evolution of language. *Current Anthropology* 34 (2), 184-93
- Aiello, L.C. and Wheeler, P. 1995. The expensive-tissue hypothesis. *Current Anthropology* 36 (2), 199-221
- Aksoy, H. and Kavvas, M.L. 2005. A review of hillslope and watershed scale erosion and sediment transport models. *Catena* 64, 247-71
- Aksu, A.E., Hall, J. and Yaltirak, C. 2005. Miocene to Recent tectonic evolution of the eastern Mediterranean: new pieces of the old Mediterranean puzzle. *Marine Geology* 221, 1-13
- Aksu, A.E., Yaşar, D. and Mudie, P.J. 1995. Origin of late Glacial-Holocene hemipelagic sediments in the Aegean Sea: clay mineralogy and carbonate cementation. *Marine Geology* 123, 33-59
- Alfaro, P., Delgado, J., Sanz de Galdeano, C., Galino-Zaldívar, J., García-Tortosa, F.J., López-Garrido, A. C., López-Casado, C., Marín-Lechado, C., Gil, A. and Borque, M.J. 2008. The Baza Fault: a major active extensional fault in the central Betic Cordillera (south Spain). *International Journal of Earth Sciences (Geologische Rundschau)* 97, 1353-65
- Allen, H.D. 2001. *Mediterranean Ecogeography*. Harlow: Pierson Education Limited.
- Allen, H.D. 2003. Response of past and present Mediterranean ecosystems to environmental change. *Progress in Physical Geography* 27 (3), 359-77
- Allen, H.D. 2009. Vegetation and ecosystem dynamics. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 203-27. Oxford: Oxford University Press
- Allen, J.R.M., Brandt, U., Brauer, A., Hubberten, H.-W., Huntley, B., Keller, J., Kraml, M., Mackensen, A., Mingram, J., Negendank, J.F.W., Nowaczyk, N.R., Oberhänsli, H., Watts, W.A., Wulf, S. and Zolitschka, B. 1999. Rapid environmental changes in southern Europe during the last glacial period. *Nature* 400, 740-43
- Alley, R.B. and Ágústssdóttir, A.M. 2005. The 8k event: cause and consequences of a major Holocene abrupt climate change. *Quaternary Science Reviews* 24, 1123-49
- Alley, R.B., Marotzke, J., Nordhaus, W.D., Overpeck, J.T., Pielke Jr., D.M., Pierrehumbert, R.T., Rhines, P.B., Stocker, T.F., Talley, L.D. and Wallace, J.M. 2003. Abrupt climate change. *Science* 299, 2005-10
- Alpersen-Afil, N. 2008. Continual fire-making at Gesher benot Ya'akov, Israel. *Quaternary Science Reviews* 27, 1733-9
- Amato, A., Aucelli, P.P.C. and Cinque, A. 2003. The long-term denudation rate in the Southern Apennines Chain (Italy): a GIS-aided estimation of the rock volumes eroded since middle Pleistocene time. *Quaternary International* 101-102, 3-11
- Ammerman, A.J., Efstratiou, N. and Adam, E. 1999. First evidence for the Palaeolithic in Aegean Thrace. In G. N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the*

- ICOPAG Conference, Ioannina, September 1994, 211-4. London: British School at Athens Studies 3
- Amorosi, A., Caporale, L., Cibin, U., Colalongo, M.L., Pasini, G., Lucchi, F.R., Severi, P. and Vaiani, S.C. 1998. The Pleistocene littoral deposits (Imola Sands) of the northern Apennine foothills. *Giornale di Geologia* 60, 83-118
- Anastasakis, G., Piper, D.J.W., Dermitzakis, M.D. and Karakitsios, V. 2006. Upper Cenozoic stratigraphy and paleogeographic evolution of Myrtoon and adjacent basins, Aegean Sea, Greece. *Marine and Petroleum Geology* 23, 353-69
- Anderson, A., Barrett, J. and Boyle, K. (eds) 2010. *Global origins (and development) of seafaring*. Cambridge: McDonald Institute for Archaeological Research
- Andrefsky, W. (ed.) 2008. *Lithic technology: methods of production, use, and curation*. Cambridge: Cambridge University Press.
- Andreikos, A. 1993. *Oi Katoteris paleolithikes lithotechnies tis Dytikis Epirou kai tou Ioniou*. Athens (in Greek)
- Andreou, S. and Kotsakis, K. 1994. Prehistoric rural communities in perspective: the Langadas Survey Project. In N. Doukellis and G. Mendoni (eds), *Structures rurales et société antiques*, 17-25. Paris
- Angelier, J. 1978. Tectonic evolution of the Hellenic Arc since the Late Miocene. *Tectonophysics* 49, 23-36
- Angelier, J., N. Lyberis, X. Le Pichon, E. Berrier and Huchon, P. 1982. The tectonic development of the Hellenic arc and the Sea of Crete: a synthesis. *Tectonophysics* 86, 159-196
- Anthopoulou, B., Panagopoulos, A. and Karyotis, Th. 2006. The impact of land degradation on landscape in Northern Greece. *Landslides* 3, 289-94
- Antonoli, F., Kershaw, S., Renda, P., Rust, D., Belluomini, G., Cerasoli, M., Radtke, U. and Silenzi, S. 2006. Elevation of the last interglacial highstand in Sicily (Italy): a benchmark of coastal tectonics. *Quaternary International* 145-146, 3-18
- Anzidei, A.P. and Arnoldus Huyzendveld, A. 1992. The Lower Palaeolithic site of La Polledrara di Ceganibbio (Rome, Italy). In E. Herring, R. Whitehouse, and J. Wilkins (eds), *New developments in Italian Archaeology, Part I, Papers of the Fourth Conference of Italian Archaeology*, 141-53. London: Accordia Research Institute
- Arribas, A. and Palmqvist, P. 1999. On the ecological connection between sabre-tooths and hominids: faunal dispersal events in the Lower Pleistocene and a review of the evidence for the first human arrival in Europe. *Journal of Archaeological Science* 26, 571-85
- Arsebük, G. and Özbaşaran, M. 1999. Pleistocene archaeology at the cave of Yarimbürgaz in eastern Thrace/Turkey: preliminary results. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 59-72. London: British School at Athens Studies 3
- Arsuaga, J.L., Martínez, I., Gracia, A., Carretero, J.M., Lorenzo, C., García, N. and Ortega, A.I. 1997. Sima de los Huesos (Sierra de Atapuerca, Spain): the site. *Journal of Human Evolution* 33, 109-27
- Arzarello, M., Marcolini, F., Pavia, G., Pavia, M., Petronio, C., Petrucci, M., Rook, L. and Sardella, R. 2007. Evidence of earliest human occurrence in Europe: the site of Piro Nord (Southern Italy). *Naturwissenschaften* 94, 107-12
- Arzarello, M., Marcolini, F., Pavia, G., Pavia, M., Petronio, C., Petrucci, M., Rook, L. and Sardella, R. 2009. The lithic industry of the Early Pleistocene site of Piro Nord (Apricena, South Italy): the evidence of a human occupation between 1.3 and 1.7 Ma. *L'Anthropologie* 113, 47-58
- Ascenzi, A., Biddittu, I., Cassoli, P.F., Segre, A.G. and Segre-Naldini, E. 1996. A calvarium of late Homo erectus from Ceprano, Italy. *Journal of Human Evolution* 31, 409-23
- Athanassiou, A. 2000. Presence of fossil Elephants in the area of Penios Valley (NW Peloponnesus, Greece). *Annales Géologiques des Pays Helléniques* 38, 63-76
- Athanassiou, A. 2001. New findings of fossil large mammal remains in the Penios Valley (area of Larissa, Thessaly, Greece). *Bulleting of the Geological Society of Greece XXXIV* (2), 533-39.
- Athanassiou, A. 2002. Neogene and Quaternary faunas of Thessaly. *Annales Géologiques des Pays Helléniques XXXIX* (A), 279-93
- Athanassiou, A. and Kostopoulos, D.S. 2001. Proboscidea of the Greek Pliocene-Early Pleistocene faunas: biochronological and palaeoecological implications. *Proceedings of the 1st International Congress 'The World of Elephants'*, 85-90
- Baena, J., Lordikpanidze, D., Cuartero, F., Ferring, R., Zhvania, D., Martín, D., Shelia, T., Bidzinashuili, G., Roca, M. and Rubio, D. 2010. Technical and technological complexity in the beginning: the study of Dmanisi lithic assemblage. *Quaternary International* 223-224, 45-53
- Bailey, G. 1992. The Palaeolithic of Klithi in its wider context. *Annual of the British School at Athens* 87: 1-28.
- Bailey, G.N. (ed.) 1997. *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece*, 2 vols. Cambridge: McDonald Institute for Archaeological Research

- Bailey, G. 2004. World prehistory from the margins: the role of coastlines in human evolution. *Journal of Interdisciplinary Studies in History and Archaeology* 1 (1), 39-50
- Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C. and Zachos, K. (eds), 1999. *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*. London: British School at Athens Studies 3
- Bailey, G., Cadbury, T., Galanidou, N. and Kotjabopoulou, E. 1997. Rockshelters and open-air sites: survey strategies and regional site distributions. In G.N. Bailey, (ed.), *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece*, vol. 2: *Klithi in its local and regional setting*, 521-36. Cambridge: McDonald Institute for Archaeological Research
- Bailey, G., Carrión, J.S., Fa, D.A., Finlayson, C., Finlayson, G. and Rodriguez-Vidal, J. 2008. The coastal shelf of the Mediterranean and beyond: corridor and refugium for human populations in the Pleistocene. *Quaternary Science Reviews* 27, 2095-99
- Bailey, G.N., Carter, P.L., Gamble, C.S. and Higgs, H.P. 1983. Asprochaliko and Kastritsa: further investigations of Palaeolithic settlement and economy in Epirus (north-west Greece). *Proceedings of the Prehistoric Society* 49, 15-42
- Bailey, G.N. and Flemming, N. 2008. Archaeology of the continental shelf: marine resources, submerged landscapes and underwater archaeology. *Quaternary Science Reviews* 27, 2153-65
- Bailey, G., King, G. and Strurdy, D. 1993. Active tectonics and land-use strategies: a Palaeolithic example from northwest Greece. *Antiquity* 67, 292-312
- Bailey, G.N., Papakonstantinou V. and Sturdy, D. 1992. Asprochaliko and Kokkinopilos: TL dating and reinterpretation of Middle Palaeolithic sites in Epirus, north-west Greece. *Cambridge Archaeological Journal* 2, 136-44
- Balco, G. and Stone, J.O.H. 2005. Measuring middle Pleistocene erosion rates with cosmic-ray-produced nuclides in buried alluvial sediment, Fisher Valley, southeastern Utah. *Earth Surface Processes and Landforms* 30, 1051-167
- Ballantyne, C.K. 2001. Paraglacial geomorphology. *Quaternary Science Reviews* 21, 1935-2017
- Ballard, R.D. (ed.) 2008. *Archaeological Oceanography*. New Jersey: Princeton University Press
- Bard, E., Antonioli, F. and Silenzi, S. 2002. Sea-level during the penultimate interglacial period based on a submerged stalagmite from Argentarola Cave. *Earth and Planetary Science Letters* 196, 135-46
- Bard, E., Hamelin, B. and Fairbanks, R.G. 1990. U-Th ages obtained by mass spectrometry in corals from Barbados: sea level during the past 130 000 years. *Nature* 346, 456-58
- Bar-Matthews, M., Ayalon, A., Kufman, A. and Wasserburg, G.J. 1999. The Eastern Mediterranean palaeoclimate as a reflection of regional events: Soreq cave, Israel. *Earth and Planetary Science Letters* 166, 85-95
- Barsky, D., Celiberti, V., Cauche, D., Grégoire, S., Lebègue, F., de Lumley, H. and Toro-Moyano, I. 2010. Raw material discernment and technological aspects of the Barranco León and Fuente Nueva 3 stone assemblages (Orce southern Spain). *Quaternary International* 223-224, 201-19
- Bartzokas, A., Lolis, C. J. and Metaxas, D.A. 2003. A study on the intra-annual variation and the spatial distribution of precipitation amount and duration over Greece on a 10 day basis. *International Journal of Climatology* 23, 207-22
- Bar-Yosef, O. 1994. The Lower Palaeolithic of the Near East. *Journal of World Prehistory* 8, 211-265.
- Bar-Yosef, O. 1998. Early colonizations and cultural continuities in the Lower Palaeolithic of western Asia. In M.D. Petraglia and R. Korisettar (eds), *Early human behavior in global context: the rise and diversity of the Lower Palaeolithic record*, 215-72. London: Routledge
- Bar-Yosef, O. and Belfer-Cohen, A. 2001. From Africa to Eurasia –early dispersals. *Quaternary International* 75, 19-28
- Bar-Yosef, O. and Van Peer, P. 2009. The chaîne opératoire approach in Middle Paleolithic archaeology. *Current Anthropology* 50 (1), 103-31
- Bartolini, C. 2003. When did the Northern Apennine become a mountain chain? *Quaternary International* 101-102, 75-80
- Bartolini, C., D'Agostino, N. and Dramis, F. 2003. Topography, exhumation, and drainage network evolution of the Apennines. *Episodes* 26 (3), 212-6
- Begun, D.R. 2009. Dryopithecins, Darwin, de Bonis, and the European origin of the African apes and human clade. *Geodiversitas* 31 (4), 789-816
- Bell, R.E., McNeill, L.C., Bull, J.M., Henstock, T.J., Collier, R.E.L. and Leeder, M.R. 2009. Fault architecture, basin structure and evolution of the Gulf of Corinth Rift, central Greece. *Basin Research* 21, 824-55
- Belmaker, M., Tchernov, E., Condemi, S. and Bar-Yosef, O. 2002. New evidence for hominid presence in the Lower Pleistocene of the southern Levant. *Journal of Human Evolution* 43, 43-56

- Benito-Calvo, A., Pérez-González, A., Magri, O. and Meza, P. 2009. Assessing regional geodiversity: the Iberian Peninsula. *Earth Surface Processes and Landforms* 34, 1433-45
- Berger, A. 1986. Desertification in a changing climate with a particular attention to the Mediterranean countries. In R. Fantechi and N.S. Margaris (eds), *Desertification in Europe: Proceedings of the Information Symposium in the EEC Programme on Climatology, Mytilene, Greece, 1984*, 15-34. Dordrecht: Reidel Publishing
- Bermúdez de Castro, J.M., Arsuaga, J.L., Carbonell, E., Rosas, A., Martínez I. and Morsuaga, M. 1997. A hominid from the Lower Pleistocene of Atapuerca, Spain: possible ancestor to Neanderthals and modern humans. *Science* 276, 1392-95
- Bermúdez de Castro, J.M., Martínón-Torres, M., Carbonell, E., Sarmiento, S., Rosas, A., van der Made, J. and Lozano, M. 2004. The Atapuerca sites and their contribution to the knowledge of human evolution in Europe. *Evolutionary Anthropology* 13, 25-41
- Bermúdez de Castro, J.M., Pérez-González, A., Martínón-Torres, M., Gómez-Robles, A., Rosell, J., Prado, L., Sarmiento, S. and Carbonell, E. 2008. A new early Pleistocene hominin mandible from Atapuerca-TD6, Spain. *Journal of Human Evolution* 55, 729-35
- Bertoldi, R., Rio, D. and Thunell, R. 1989. Pliocene-Pleistocene vegetational and climatic evolution of the south-central Mediterranean. *Palaeogeography, Palaeoclimatology, Palaeoecology* 72, 263-75
- Besonen, M.R., Rapp, G.R. and Jing, Z. 2003. The lower Acheron River Valley: ancient accounts and the changing landscape. In J. Wiseman and K. Zachos (eds.), *Landscape Archaeology in Southern Epirus, Greece I*, Hesperia suppl. 32, 199-263. Athens: American School of Classical Studies at Athens
- Biberson, P. 1961. *Le Paleolithique inferieur du Maroc atlantique*. Rabat: Publications du Service des Antiquités du Maroc, fascicule 16
- Bicho, N. and Haws, J. 2008. At the land's end: marine resources and the importance of fluctuations in the coastline in the prehistoric hunter-gatherer economy of Portugal. *Quaternary Science Reviews* 27, 2166-75
- Biddittu, I., Cassoli, P.F., Radicati di Brozolo, F., Segre, A. G., Segre-Naldini, E. and Villa, I. 1979. Anagni, a K/Ar dated Lower and Middle Pleistocene site, Central Italy: preliminary report. *Quaternaria* XXI, 53-71
- Billiris, H., Paradissis, D., Veis, G., England, P., Featherstone, W., Parsons, B., Cross, P., Rands, P., Rayson, M., Sellers, P., Ashkenazi, V., Davidson, M., Jackson, J. and Ambraseys, N. 1991. Geodetic determination of tectonic deformation in central Greece from 1900 to 1988. *Nature* 350, 124-29
- Bintanja, R., van de Wal, R.S.W. and Oerlemans, J. 2005. Modelled atmospheric temperatures and global sea levels over the past million years. *Nature* 437, 125-28
- Bintliff, J.L. 1992. Erosion in the Mediterranean lands: a reconsideration of pattern, process and methodology. In J. Boardman and M. Bell (eds), *Past and Present Soil Erosion*, 125-31. Oxford: Oxbow Books
- Bintliff, J.L. 2002. Time, process and catastrophism in the study of Mediterranean alluvial history: a review. *World Archaeology* 33 (3), 417-35
- Bintliff, J.L. 2005. Human impact, land-use history and the surface archaeological record: a case study from Greece. *Geoarchaeology* 20 (2), 135-47
- Bischoff, J.L., Williams, R.W., Rosenbauer, R.J., Aramburu, A., Arsuaga, J.L., García, N. and Cuenca-Bescós, G. 2007. High-resolution U-series dates from the Sima de los Huesos hominids yields 600 kys: implications for the evolution of the early Neanderthal lineage. *Journal of Archaeological Science* 34, 763-70
- Bishop, P. 2007. Long-term landscape evolution: linking tectonics and surface processes. *Earth Surface Processes and Landforms* 32, 329-65
- Blondel, J. 2009. The nature and origin of the vertebrate fauna. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 139-63. Oxford: Oxford University Press
- Bloom, A.L. 2002. *Geomorphology: A Systematic Analysis of Late Cenozoic Landforms*. New Delhi: Prentice Hall of India, 3rd edition
- Boëda, E. 1995. Levallois: a volumetric construction, methods, a technique. In H.L. Dibble and O. Bar-Yosef (eds), *The definition and interpretation of Levallois technology*, Monographs in World Archaeology 23, 41-68. Madison: Prehistory Press
- Bond, G., Shower, W., Cheseby, M., Lotti, R., Almasi, P., de Menocal, P., Priore, P., Cullen, H., Hadjas, I. and Bonani, G. 1997. A pervasive millennial-scale cycle in North Atlantic Holocene and Glacial climates. *Science* 258, 1257-66
- Brauer, A., Allen, J.R.M., Mingram, J., Dulski, P., Wulf, S. and Huntley, B. 2007. Evidence for last interglacial chronology and environmental change from Southern Europe. *Proceedings of the National Academy of Science (USA)* 104 (2) 450-55
- Bridgland, D.R., Maddy, D. and Bates, M. 2004. River terrace sequences: templates for Quaternary geochronology and marine-terrestrial correlation. *Journal of Quaternary Science* 19 (2), 203-18
- Bridgland, D.R. and Westaway, R. 2008a. Preservation patterns of Late Cenozoic fluvial deposits and their implications: results from IGCP 449. *Quaternary International* 189, 5-38

- Bridgland, D.R. and Westaway, R. 2008b. Climatically controlled river terrace staircases: a worldwide Quaternary phenomenon. *Geomorphology* 98, 285-315
- Broodbank, C. 2006. The origins and early development of Mediterranean maritime activity. *Journal of Mediterranean Archaeology* 19 (2), 199-230
- Brown, A.G., Carey, C., Erkens, G., Fuchs, M., Hoffmann, T., Macaire, J.-J., Moldenhauer, K.M. and Walling, D. E. 2009. From sedimentary records to sediment budgets: multiple approaches to catchment sediment flux. *Geomorphology* 108, 35-47
- Brusden, D. 2001. A critical assessment of the sensitivity concept in geomorphology. *Catena* 42, 99-123
- Brusden, D. and Thornes, J.B. 1979. Landscape sensitivity and change. *Transactions of the Institute of British Geographers*, New Series 4 (4), 463-84
- Burchfiel, B.C., Nakov, R. and Tzankov, T. 2003. Evidence from the Mesta half-graben, SW Bulgaria, for the Late Eocene beginning of Aegean extension in the Central Balkan Peninsula. *Tectonophysics* 375, 61-76
- Butzer, K.W. 1965. Acheulian occupation sites at Torralba and Ambrona, Spain: their geology. *Science* 150, 1718-21
- Butzer, K.W. 1982. *Archaeology as Human Ecology: method and theory for a contextual approach*. Cambridge: Cambridge University Press
- Butzer, K.W. 2005. Environmental history in the Mediterranean world: cross-disciplinary investigation of cause-and-effect from degradation and soil erosion. *Journal of Archaeological Science* 32, 1773-1800
- Cachel, S. and Harris, J.W.K. 1998. The lifeways of Homo erectus inferred from archaeology and evolutionary ecology: a perspective from East Africa. In M.D. Petraglia and R. Korisettar (eds), *Early human behavior in global context: the rise and diversity of the Lower Palaeolithic record*, 104-29. London: Routledge
- Candy, I. and Black, S. 2009. The timing of Quaternary calcrete development in semi-arid southeast Spain: investigating the role of climate on calcrete genesis. *Sedimentary Geology* 218, 6-15
- Candy, I., Black, S. and Sellwood, B.W. 2004. Quantifying timescales of pedogenic calcrete formation using U-series disequilibria. *Sedimentary Geology* 170, 177-87
- Caputo, R. 1990. *Geological and structural study of the recent and active brittle deformation of the Neogene-Quaternary basins of Thessaly (Central Greece)*. Thessaloniki: Aristotle University of Thessaloniki Scientific Annals 12
- Caputo, R. 1993. The Rodia Fault System: an active complex shear zone (Larissa Plain, Central Greece). *Bulletin of the Geological Society of Greece* XXVIII (1), 447-56
- Caputo, R. 2007. Sea-level curves: Perplexities of an end-user in morphotectonic applications. *Global and Planetary Change* 57, 417-23
- Caputo, R., Bravard, J.-P. and Helly, B. 1994. The Pliocene-Quaternary tecto-sedimentary evolution of the Larissa Plain (Eastern Thessaly, Greece). *Geodinamica Acta* 7 (4), 219-31
- Caputo, R. and Helly, B. 2005. The Holocene activity of the Rodia Fault, Central Greece. *Journal of Geodynamics* 40, 153-69
- Caputo R., Helly, B., Pavlides, S. and Papadopoulos, G. 2006. Archaeo- and palaeoseismological investigations in Northern Thessaly, Greece: Insights for the seismic potential of the region. *Natural Hazards* 39, 195-212
- Caputo, R. and Pavlides, S. 1993. Late Cenozoic geodynamic evolution of Thessaly and surroundings (central-northern Greece). *Tectonophysics* 223, 339-62
- Carbonell, E., Bermúdez de Castro, J.M., Arsuaga, J.L., Allué, E., Bastir, M., Benito, A., Cáceres, I., Canals, T., Díez, J.C., van der Made, J., Mosquera, M., Ollé, A., Pérez-Gonzales, A., Rodríguez, X.P., Rosas, A., Rosell, J., Sala, R., Vallverdu, J. and Vergés, J.M. 2005. An Early Pleistocene hominin mandible from Atapuerca-TD6, Spain. *Proceedings of the National Academy of Sciences of the United States of America* 102 (16), 5674-8
- Carbonell, E., Bermúdez de Castro, J.M., Arsuaga, J.L., Díez, J.C., Rosas, A., Cuenca-Bescós, G., Sala, R., Mosquera, M. and Rodríguez, X.P. 1995. Lower Pleistocene hominids and artifacts from Atapuerca-TD6 (Spain). *Science* 269, 826-30
- Carbonell, E., Bermúdez de Castro, J.M., Parés, J.M., Pérez-Gonzales, A., Cuenca-Bescós, G., Ollé, A., Mosquera, M., Huguet, R., van der Made, J., Rosas, A., Sala, R., Vallverdu, J., García, N., Granger, D.E., Martínón-Torres, M., Rodríguez, X.P., Stock, G.M., Vergés, J.M., Allué, E., Burjachs, F., Cáceres, I., Canals, A., Benito, A., Díez, C., Lozano, M., Mateos, A., Navazo, M., Rodríguez, J., Rosell, J. and Arsuaga, J.L. 2008. The first hominin in Europe. *Nature* 452, 465-70
- Carbonell, E., Mosquera, M., Rodríguez, X.P., Sala, R. and van der Made J. 1999. Out of Africa: the dispersal of the earliest technical systems reconsidered. *Journal of Anthropological Archaeology* 18, 119-36

- Carbonell, E. and Rodríguez, X.P. 2006. The first human settlement of Mediterranean Europe. *Comptes Rendus Palevol* 5, 291-8
- Carmody, R.N. and Wrangham, R.W. 2009. The energetic significance of cooking. *Journal of Human Evolution* 57, 379-91
- Carrigy, M.A. 1970. Experiments on the angles of repose of granular materials. *Sedimentology* 14, 147-58
- Carrión, J.S., Finlayson, C., Fernández, S., Finlayson, G., Allué, E., López-Sáez, J.A., López-García, P., Gil-Romera, G., Bailey, G. and González-Sampériz, P. 2008. A coastal reservoir of biodiversity for Upper Pleistocene human populations: palaeoecological investigations in Gorham's Cave (Gibraltar) in the context of the Iberian Peninsula. *Quaternary Science Reviews* 27, 2118-35
- Casana, J. 2008. Mediterranean valleys revisited: linking soil erosion, land use and climate variability in the Northern Levant. *Geomorphology* 101, 429-42
- Casas-Sainz, A.M. and de Vicente, G. 2009. On the tectonic origin of Iberian topography. *Tectonophysics* 474, 214-235
- Casermeyro, M.A., Molina, J.A., de la Cruz Caravaca, M. T., Hernando Costa J., Hernando Massanet, M.I. and Moreno, P.S. 2004. Influence of shrubs on runoff and sediment loss in soils of Mediterranean climate. *Catena* 57, 91-107
- Cela-Conde, C. and Ayala, F. 2003. Genera of the human lineage. *Proceedings of the National Academy of Sciences of the United States of America* 100 (13), 7684-89
- Cendrero, A. and F. Dramis 1996. The contribution of landslides to landscape evolution in Europe. *Geomorphology* 15, 191-211
- Chavaillon, J., Chavaillon, N. and Hours, F. 1967. Industries paléolithiques de l'Élide I, région d'Amaïas. *Bulletin de Correspondance Hellénique* 91, 151-201
- Chavaillon, J., Chavaillon, N. and Hours, F. 1969. Industries paléolithiques de l'Élide II, région de Kastron. *Bulletin de Correspondance Hellénique* 93, 97-151
- Chazan, M. 1997. Redefining Levallois. *Journal of Human Evolution* 33, 719-35
- Cheddadi, R., de Beaulieu, J.-L., Jouzel, J., Andrieu-Ponel, V., Laurent, J.-M., Reille, M., Raynaud, D. and Bar-Hen, A. 2005. Similarity of vegetation dynamics during interglacial periods. *Proceedings of the National Academy of Science (USA)* 102 (39), 13939-43
- Chelidonio, G. 2001. Manufatti litici su Ciottolo da Milos (isole Cicladi). *Pegaso: Rivista di Cultura Mediterranea* 1, 117-44
- Cherry, J.F. and Parkinson, W.A. 2003. Lithic artefacts from surveys: a comparative evaluation of recent evidence from the southern Aegean. In N. Kardulias and R. Yerkes (eds), *Written in Stone: the multiple dimensions of lithic analysis*, 35-57. Maryland: Lexington Books
- Choi, K. and Driwanoro, D. 2007. Shell tool use by early members of *Homo erectus* in Sangiran, central Java, Indonesia: cut mark evidence. *Journal of Archaeological Science* 34, 48-58
- Church, M. and Hassan, M.A. 1992. Size and distance of unconstrained clasts on a streambed. *Water Resources Research* 28, 299-303
- Clark, J.D. 1992. The Earlier Stone Age / Lower Palaeolithic in North Africa and the Sahara. In F. Klees and R. Kuper (eds), *New light on the northeast African past*, 17-37. Köln: Heinrich-Barth Institut
- Clark, J.D. 1994. The Acheulian Industrial Complex in Africa and elsewhere. In R.S. Corruccini and R.L. Ciochon (eds) *Integrative Paths to the Past -Paleoanthropological Advances in Honor of F. Clark Howell*, 451-69. Englewood Cliff, New Jersey: Prentice Hall
- Clark, P.U. and Mix, A.C. 2002. Ice sheets and sea level of the Last Glacial Maximum. *Quaternary Science Reviews* 21, 1-7
- Clark, M. and Small, J. 1982. *Slopes and Weathering*. Cambridge: Cambridge University Press
- Cloetingh, S.A.P.L., Ziegler, P.A., Bogaard, P.J.F., Andriessen, P.A.M., Artemieva, I.M., Bada, G., van Balen, R.T., Beeckman, F., Ben-Avraham, Z., Brun, J.-P., Bunge, H.P., Burov, E.B., Carbonell, R., Facenna, C., Friedrich, A., Gallart, J., Green, A.G., Heidbach, O., Jones, A.G., Matenco, L., Mosar, J., Oncken, O., Pascal, C., Peters, G., Sliupa, S., Soesso, A., Spakman, W., Stephenson, R.A., Thybo, H., Torsvik, T., de Vicente, G., Wenzel, F., Wortel, M.J. R. and TOPO-EUROPE Working Group 2007. TOPO-EUROPE: The geoscience of coupled deep Earth-surface processes. *Global and Planetary Change* 58, 1-118
- Codilean, A.T., Bishop, B. and Hoey, T.B. 2006. Surface process models and the links between tectonics and topography. *Progress in Physical Geography* 30 (3), 307-33
- Collier, R.E.L., Leeder, M.R. and Jackson, J.A. 1995. Quaternary drainage development, sediment fluxes and extensional tectonics in Greece. In J. Lewin, M.G. Macklin and J.C. Woodward (eds), *Mediterranean Quaternary River Environments*, 31-44. Rotterdam: Balkema
- Collins, M.B., Lykousis, V. and Ferentinos, G. 1981. Temporal variations in sedimentation patterns: NW Aegean Sea. *Marine Geology* 43, 39-48

- Coltorti, M., Cremaschi, M., Delitala, M.C., Esu, D., Fornaseri, M., McPherron, A., Nicoletti, M., van Otterloo, R., Peretto, C., Sala, B., Schmidt, V. and Sevink, J. 1982. Reversed magnetic polarity at an early Lower Palaeolithic site in Central Italy. *Nature* 300, 173-6
- Coltorti, M., Feraud, G., Marzoli, A., Peretto, C., Tonthat, T., Voinchet, P., Bahain, J.-J., Minelli, A. and Thun Hohenstein, U. 2005. New $^{40}\text{Ar}/^{39}\text{Ar}$, stratigraphic and palaeoclimatic data on the Isernia La Pineta Lower Palaeolithic site, Molise, Italy. *Quaternary International* 131, 11-22
- Conacher, A.J. and Delrymple, J.B. 1977. The nine-unit land-surface model: an approach to pedogeomorphic research. *Geoderma* 18, 1-154
- Conacher, A.J. and Sala, M. 1998. *Land degradation in Mediterranean environments of the world: nature and extent, causes and solutions*. Chichester: John Wiley & Sons.
- Constantini, R., Ottini, L., Caramiello, S., Palmirotta, R., Mallegni, F., Rossi, A., Frati, L. and Capasso, L. 2001. Taphonomy of the fossil hominid bones from the Acheulean site of Castel di Guido near Rome, Italy. *Journal of Human Evolution* 41, 211-25
- Coulthard, T.J., Lewin, J. and Macklin, M.G. 2005. Modelling differential catchment response to environmental change. *Geomorphology* 69, 222-41
- Cramp, A., Collins, M. and West, R. 1988. Late Pleistocene-Holocene sedimentation in the NW Aegean Sea: a palaeoclimatic, palaeoceanographic reconstruction. *Palaeogeography, Palaeoclimatology, Palaeoecology* 68, 61-77
- Cubuk, G.A. 1976. Altpaläolithische Funde von den Mittelmeerrassens bei Nea Skala auf Kephallinia (Griechenland). *Archäologisches Korrespondenzblatt* 6, 175-81
- Cuenca-Bescós, G., Laplana, C. and Canudo, J.I. 1999. Biochronological implications of the Arvicolidae (Rodentia, Mammalia) from the Lower Pleistocene hominid-bearing level of Trinchera Dolina 6 (TD6, Atapuerca, Spain). *Journal of Human Evolution* 37, 353-73
- Dakaris, S.I., Higgs, E.S. and Hey, R.W. 1964. The Climate, environment and industries of Stone Age Greece: Part I. *Proceedings of the Prehistoric Society* 30, 199-244
- Dalrymple, J.B., Blong, R.J. and Conacher, A.J. 1968. An hypothetical nine unit landsurface model. *Zeitschrift für Geomorphologie* 12 (1), 60-76
- Darlas, A. 1994. Le Paléolithique inférieur et moyen de Grèce. *L'Anthropologie* 98, 305-28
- Darlas, A. 1995a. The earliest occupation of Europe: the Balkans. In W. Roebroeks and T. van Kolfschoten (eds), *The Earliest Occupation of Europe. Proceedings of the European Science Foundation Workshop at Tautavel (France), November 1993*, 51-59. Leiden: Leiden University Press
- Darlas, A. 1995b. L'industrie du paléolithique moyen de Mavri Myti (Lakkopetra, Grèce). *Bulletin de la Société Préhistorique Française* 92 (3), 390-98
- Darlas, A. 1999. Palaeolithic research in Western Achaia. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 303-10. London: British School at Athens Studies 3
- Darlas, A. 2003. Palaeolithic finds from the Megalopolis basin: their relation to the fossils of the same area. In A. Vlachopoulos and K. Birtacha (eds), *ARGONAUTIS: Timetikos tomos yia ton Kathegete Christo G. Douma apo tous mathetes tou sto Panepistimio Athenon (1980-2000)*, 27-37. Athens: Kathimerini (in Greek)
- Darlas, A. 2007. The Mousterian of Greece under the light of recent research. *L'Anthropologie* 111, 346-66
- Darlas, A. and de Lumley, H. 1999. Palaeolithic research in Kalamakia Cave, Areopolis, Peloponnese. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 293-302. London: British School at Athens Studies 3
- Darlas, A., Karkanis, P., Palli, O. and Papadea, A. 2007. Palaeolithic research on south-west Corfu. *Archaeologia Analekta ex Athinon* 39, 11-30 (2006) (in Greek)
- Dart, C.J., Collier, R.E.L., Gawthorpe, R.L., Keller, J.V. A. and Nichols, G. 1994. Sequence stratigraphy of Pliocene-Quaternary synrift, Gilbert-type fan deltas, northern Peloponnesos, Greece. *Marine and Petroleum Geology* 11 (5), 545-560
- Davis, W.M. 1899. The geographical cycle. *Geographical Journal* 14, 481-504
- Debénath, A. and Dibble, H.L. 1994. Handbook of Paleolithic typology, volume one: Lower and Middle Paleolithic of Europe. Philadelphia: University of Philadelphia
- Dedkov, A.P. and Moszherin, V.T. 1992. Erosion and sediment yield in mountain areas of the world. In D.E. Walling, T.R. Davies and B. Hasholt (eds), *Erosion, Debris Flows and Environment in Mountain Regions of the World*, 29-36. IAHS Publication 209
- Della Seta, M., Del Monte, M., Fredi, P. and Lupia Palmieri, E. 2009. Space-time variability of denudation rates at the catchment and hillslope scales on the

- Tyrrhenian side of Central Italy. *Geomorphology* 107, 161-77
- Demas, G.P. and Rabenhorst, M.C. 2001. Factors of subaqueous soil formation: a system of quantitative pedology for submersed environments. *Geoderma* 102, 189-204
- Demitrack, A. 1986. *The Late Quaternary geologic history of the Larissa Plain, Thessaly, Greece: tectonic, climatic and human impact on the landscape*. Unpublished PhD thesis, Stanford University
- Dennell, R. 2003. Dispersal and colonization, long and short chronologies: how continuous is the Early Pleistocene record for hominids outside East Africa? *Journal of Human Evolution* 45, 421-40
- Dennell, R. 2009. Transitions: behavioral change in the Early Pleistocene. In M. Camps and P.R. Chauhan (eds), *Sourcebook of Palaeolithic transitions: methods, theories and interpretations*, 229-34. New York: Springer
- Dennell, R., Martínón-Torres, M. and Bermúdez de Castro, J.M. 2010. Out of Asia: the initial colonisation of Europe in the Early and Middle Pleistocene. *Journal of Human Evolution* 223-224, 439
- Dennell, R. and Roebroeks, W. 1996. The earliest colonization of Europe: the short chronology revisited. *Antiquity* 70, 535-42
- Dennell, R. and Roebroeks, W. 2005. An Asian perspective on early human dispersal from Africa. *Nature* 438, 1099-1104
- Derricourt, R. 2005. Getting 'Out of Africa': sea crossings, land crossings and culture in the hominid migrations. *Journal of World Prehistory* 19, 119-32
- Dermitzakis, M.D., Lekkas, E., Drinia, Ch. and Triantafyllou M.B. 2000. Stratigraphic and tectonosedimentary evolution of Zakynthos Island. *Proceedings of the 6th Panionian Congress* 1, 235-48
- Dermitzakis, M.D., Papanikolaou, D. and Karotsieris, Z. 1979. The marine Quaternary formations of SE Zakynthos island and their paleogeographic implications. *Proceedings of the 6th Colloquium on the Geology of the Aegean Region* 1, 407-415
- Dermitzakis, M.D. and Sondaar, P.Y. 1978. The importance of fossil mammals in reconstructing paleogeography with special reference to the Pleistocene Aegean Archipelago. *Annales Géologiques des Pays Helléniques* 29, 808-40
- Desprat, S., Sánchez-Gómez, M.F., McManus, J.F., Duprat, J. and Cortijo, E. 2009. Millennial-scale climatic variability between 340 000 and 270 000 years ago in SW Europe: evidence from a NW Iberian margin pollen sequence. *Climate of the Past* 5, 53-72
- De Vente, J. and Posen, J. 2005. Predicting soil erosion and sediment yield at the basin scale: scale issues and semi-quantitative models. *Earth-Science Reviews* 71, 95-125
- De Vente, J., Poesen, J., Verstraeten, G., Van Rompaey, A. and Govers, G. 2008. Spatially distributed modeling of soil erosion and sediment yield at regional scales in Spain. *Global and Planetary Change* 60, 393-415
- Díaz-Hernández, J.L. and Juliá, R. 2006. Geochronological position of badlands and geomorphological patterns in the Guadix-Baza basin (SE Spain). *Quaternary Research* 65, 467-77
- Dibble, H. L. 1991. Local raw material exploitation and its effects on Lower and Middle Palaeolithic assemblage variability. In A. Montet-White and S. Holen (eds), *Raw material economies among prehistoric hunter-gatherers*, Publications in Anthropology 19, 33-47. Lawrence: University of Kansas
- Digerfeldt, G., Sandgren, P. and Olson, S. 2007. Reconstruction of Holocene lake-level changes in Lake Xinias, central Greece. *The Holocene* 17 (3), 361-67
- Dimoyannis, D., Valmis, S. and Danalatos, N.G. 2006. Interill erosion on cultivated Greek soils: modeling sediment delivery. *Earth Surface Processes and Landforms* 31, 940-49
- Dincauze, D.F. 2000. *Environmental Archaeology: principles and practice*. Cambridge: Cambridge University Press
- Doboş, A. 2008. The Lower Palaeolithic of Romania: a critical review. *PaleoAnthropology* 2008, 218-33.
- Doukas, C.S. and A. Athanassiou 2003. Review of the Pliocene and Pleistocene Proboscidea (Mammalia) from Greece. In J.W.F. Reumer, J. De Vos and D. Mol (eds) *Advances in Mammoth Research: Proceedings of the Second International Mammoth Conference, Rotterdam, May 16-20 1999*, Deinsea 9, 97-110
- Dousougli, A. 1999. Palaeolithic Leukas. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès, and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 288-92. London: British School at Athens Studies 3
- Doutsos, T. and Kokkalas, S. 2001. Stress and deformation patterns in the Aegean region. *Journal of Structural Geology* 23, 455-72
- Doutsos, T., Kontopoulos, N. and Frydas, D. 1987. Neotectonic evolution of northwestern-continental Greece. *Geologische Rundschau* 76 (2), 433-50
- Dubreuil, B. 2010. Paleolithic public goods games: why human culture and cooperation did not evolve in one step. *Biology and Philosophy* 25, 53-73
- Duermeijer, C.E., Krijgsman, W., Langereis, C.G., Meulenkamp, J.E., Triantaphyllou, M.V. and Zachariasse, W.J. 1999. A Late Pleistocene clockwise rotation

- phase of Zakynthos (Greece) and implications for the evolution of the western Aegean arc. *Earth and Planetary Science Letters* 173, 315-31
- Durn, G. 2003. Terra Rossa in the Mediterranean region: parent materials, composition and origin. *Geologia Croatica* 56 (1), 83-100
- Efstratiou, N. and Ammerman, A.J. 1996. The first finds from the Palaeolithic period in Thrace. *Archaiologia kai Technes* 60, 7-12 (in Greek)
- Efstratiou, N., Biagi, P., Elefanti, P., Karkanis, P. and Ntinou, M. 2006. Prehistoric exploitation of Grevena highland zones: hunters and herders along the Pindus chain of western Macedonia (Greece). *World Archaeology* 38 (3), 415-35
- Ehlers, J. and Gibbard, P.L. 2003. Extent and chronology of glaciations. *Quaternary Science Reviews* 22, 1561-68
- Elefanti, P., Panagopoulou, E. and Karkanis, P. 2008. The transition from the Middle to the Upper Palaeolithic in the southern Balkans: the evidence from Lakonis I cave, Greece. *Eurasian Prehistory* 5, 85-96
- EPICA community members 2004. Eight glacial cycles from an Antarctic ice core. *Nature* 429, 623-8
- Erlanson, J.M. 2001. The archaeology of aquatic adaptations: paradigms for a new millennium. *Journal of Archaeological Research* 9 (4), 287-350
- European Union Maritime Policy: Facts and Figures, Greece. Available at: http://ec.europa.eu/maritimeaffairs/pdf/country_factsheets/greece_en.pdf
- Fa, D.A. 2008. Effects of tidal amplitude on intertidal resource availability and dispersal pressure in prehistoric human coastal populations: the Mediterranean-Atlantic transition. *Quaternary Science Reviews* 27, 2194-2209
- Fairbanks, R.Q. 1989. A 17000 year glacioeustatic sea-level record: influence of glacial melting rates on the Younger Dryas event and deep ocean circulation. *Nature* 342, 642-7
- Falguères, C., Bahain, J.-J., Pérez-González, A., Mercier, N., Santonja, M. and Dolo, J.-M. 2006. The Lower Acheulian site of Ambrona, Soria (Spain): ages derived from a combined ESR/U-series model. *Journal of Archaeological Science* 33, 149-57
- Falguères, C., Bahain, J.-J., Tozzi, C., Boschian, G., Dolo, J.-M., Mercier, N., Valladas, H. and Yokoyama, Y. 2008. ESR/U-series chronology of the Lower Palaeolithic palaeoanthropological site of Visogliano, Trieste, Italy. *Quaternary Geochronology* 3, 390-8
- Falguères, C., Bahain, J.-J., Yokoyama, Y., Arsuaga, J.L., Bermúdez de Castro, J.M., Bischoff, J.L. and Dolo, J.-M. 1999. Earliest humans in Europe: the age of TD6 Gran Dolina, Atapuerca, Spain. *Journal of Human Evolution* 37, 343-52.
- Fanning, P. and Holdaway, S. 2001. Stone artifact scatters in western NSW, Australia: Geomorphic controls on artifact size and distribution. *Geoarchaeology* 16 (6), 667-86
- Fanning, P.C., Holdaway, S.J., Rhodes, E.J. and Bryant, T. G. 2009. The surface archaeological record in arid Australia: geomorphic controls on preservation, exposure and visibility. *Geoarchaeology* 24 (2), 121-46
- Faure, H., Walter, R.C. and Grant, D.R. 2002. The coastal oasis: ice age springs on emerged continental shelves. *Global and Planetary Change* 33, 47-56
- Féblot-Augustins, J. 1999. Raw material transport patterns and settlement systems in the European Lower and Middle palaeolithic: continuity, change and variability. In W. Roebroeks and C. Gamble (eds), *The Middle Palaeolithic Occupation of Europe*, 193-214. Leiden: University of Leiden
- Ferentinos, G. 1992. Recent gravitative mass movements in a highly tectonically active arc system: The Hellenic Arc. *Marine Geology* 104, 93-107
- Finlayson, C. 2008. On the importance of coastal areas in the survival of Neanderthal populations during the Late Pleistocene. *Quaternary Science Reviews* 27, 2246-52
- Flemming, N.C. 1985. Ice ages and human occupation of the Continental Shelf. *Oceanus* 28, 18-26
- Flemming, N.C. 1998. Archaeological evidence for vertical tectonic movement on the continental shelf during the Palaeolithic, Neolithic and Bronze Age periods. In I.S. Stewart and C. Vita-Finzi (eds), *Coastal tectonics*, Geological Society Special Publication 146, 129-146. London: Geological Society
- Fletcher, W.J. and Sánchez-Goni, M.F. 2008. Orbital- and sub-orbital-scale climate impacts on vegetation of the western Mediterranean basin over the last 48,000 yr. *Quaternary Research* 70, 451-64
- Forsström, L. 2001. Duration of interglacials: a controversial question. *Quaternary Science Reviews* 20, 1557-86
- Freeman, L.G. 1975. Acheulean sites and stratigraphy in Iberia and the Maghreb. In K. Butzer and G. Isaac (eds.), *After the Australopithecines. Stratigraphy, Ecology, and Culture Change in the Middle Pleistocene*, 661-743. The Hague: Mouton
- French, C.A.I. 2003. *Geoarchaeology in action: studies in soil micromorphology and landscape evolution*. London: Routledge
- French, C.A.I. and Whitelaw, T.M. 1999. Soil erosion, agricultural terracing and site formation processes at Markiani, Amorgos, Greece: the micromorphological perspective. *Geoarchaeology* 14 (2), 151-89
- Freund, G. 1971. Zum Paläolithikum Thessaliens. *Prehistorische Zeitschrift* 46, 181-94

- Frogley, M.R., Tzedakis, P.C. and Heaton, T.H.E. 1999. Climate variability in northwest Greece during the Last Glacial. *Nature* 285, 1886-89
- Fuchs, M. 2007. An assessment of human versus climatic impacts on Holocene soil erosion in NE Peloponnese, Greece. *Quaternary Research* 67, 349-56
- Gabunia, L., de Lumley, M.-A., Vekua, A., Lordkipanidze, D.D. and de Lumley, H. 2002. Découverte d'un nouvel hominidé à Dmanisi (Transcaucasie, Georgie). *Comptes Rendus Palevol* 1, 243-53
- Gabunia, L., Vekua, A. and Lordkipanidze, D. 2000. The environmental contexts of early human occupation of Georgia (Transcaucasia). *Journal of Human Evolution* 38, 785-802
- Galanidou, N. 1996. 'So far away, so close': historical and theoretical perspectives on Palaeolithic and Mesolithic research in Greece. *Ariadni* 8, 7-29
- Galanidou, N. 2004. Early hominids in the Balkans. In H.I. Griffiths, B. Kryštufek and J.M. Reed (eds), *Balkan Biodiversity: Pattern and Process in the European Hotspot*, 147-65. Dordrecht: Kluwer Academic Publishers
- Gamble, C. 1999. *The Palaeolithic societies of Europe*. Cambridge: Cambridge University Press
- Gaultier, P., Brun, J.-P., Moriceau, R., Sokoutis, D., Martinod, J. and Joliver, L. 1999. Timing, kinematics and cause of Aegean extension: a scenario based on a comparison with simple analogue experiments. *Tectonophysics* 315, 31-72
- Geeson, N.A., Brabdt, C.J. and Thornes, J.B. (eds) 2002. *Mediterranean desertification: a mosaic of processes and responses*. Chichester: John Wiley & Sons
- Geraads, D., Raynal, J.-P. and Eisenmann, V. 2004. The earliest human occupation of North Africa: a reply to Sahnouni et al. (2002). *Journal of Human Evolution* 46, 751-61
- Geraga, M., Tsaila-Monopolis, St., Ioakim, Chr., Papathodorou, G. and Ferentinos, G. 2005. Short-term climate changes in the southern Aegean Sea over the last 48,000 years. *Palaeogeography, Palaeoclimatology, Palaeoecology* 220, 311-32
- Ghisetti, F. and Vezzani, L. 1999. Depth and modes of Pliocene-Pleistocene crustal extension of the Apennines (Italy). *Terra Nova* 11, 67-72
- Gibbard, P.L. and Lewin, J. 2009. River incision and terrace formation in the Late Cenozoic of Europe. *Tectonophysics* 474, 41-55
- Gibert, J., Campillo, D., Arqués, M., Garcia-Olivares, E., Borja, C. and Lowenstein, J. 1998a. Hominid status of the Orce cranial fragment reasserted. *Journal of Human Evolution* 34, 203-17
- Gibert, J., Gibert, L., Iglesias, A. and Maestro, E. 1998b. Two 'Oldowan' assemblages in the Plio-Pleistocene deposits of the Orce region, southeast Spain. *Antiquity* 72, 17-25
- Gibert, J., Sánchez, F., Ribot, F., Gibert, Ll., Iglesias, A. and El Hamouti, N. 2008. Dispersion du Genre *Homo* au sud d'Ibérie et au Maghreb: nouvelles données à propos des fossiles VM-1960 et BL-0. *L'anthropologie* 112, 48-73
- Gibert, L., Scott, G. and Ferrández-Cañadell, C. 2006. Evaluation of the Olduvai subchron in the Orce ravine (SE Spain). Implications for Plio-Pleistocene mammal biostratigraphy and the age of Orce archaeological sites. *Quaternary Science Reviews* 25, 507-25
- Giorgi, F. and P. Lionello 2008. Climate change projections for the Mediterranean region. *Global and Planetary Change* 63, 90-104
- Gkouma, M. 2009. *Past and present soil erosion in Zakynthos: a geoarchaeological study on the impact of soil erosion on archaeological distributions*. Unpublished MSc Thesis. Amsterdam: Vrije Universiteit
- Golberg, P. 1995. The changing landscape. In T.E. Levy (ed.), *The archaeology of society in the Holy Land*, 40-57. London: Leicester University Press
- Goldberg, P. and Macphail, R.I. 2006. *Practical and theoretical Geoarchaeology*. Oxford: Blackwell Publishing
- Goldsworthy, M. and Jackson, J. 2000. Active normal fault evolution in Greece revealed by geomorphology and drainage patterns. *Journal of the Geological Society, London*, 157, 967-81
- Goldsworthy, M. and Jackson, J. 2001. Migration of activity within normal fault systems: examples from the Quaternary of mainland Greece. *Journal of Structural Geology* 23, 489-506
- Goldsworthy, M., Jackson, J. and Haines, J. 2002. The continuity of active fault systems in Greece. *Geophysical Journal International* 148, 596-618
- Goren-Inbar, N. 1995. The Lower Palaeolithic of Israel. In T.E. Levy (ed.), *The archaeology of society in the Holy Land*, 93-109. London: Leicester University Press
- Goren-Inbar, N., Belitzky, S., Verosub, K., Werker, E., Kislev, M., Heimann, A., Carmi, I. and Rosenfeld, A. 1992. New discoveries at the Middle Pleistocene Acheulian site of Gesher Benot Ya'aqov, Israel. *Quaternary Research* 38, 117-28
- Goren-Inbar, N., Feibel, C.S., Verosub, K.L., Melamed, Y., Kislev, M.E., Tchernov, E. and Saragusti, I. 2000. Pleistocene milestones on the Out-of-Africa corridor at Gesher Benot Ya'aqov, Israel. *Science* 289, 944-7
- Gowlett, J.A.J. 1999. The Lower and Middle Palaeolithic, transition problems and hominid species: Greece in broader perspective. In G.N. Bailey, E. Adam, E.

- Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 43-58. London: British School at Athens Studies 3
- Gowlett, J.A.J. and Carter, P. 1997. The basal Mousterian of Asprochaliko rockshelter, Louros Valley. In G.N. Bailey (ed.), *Klithi: Palaeolithic settlement and Quaternary landscapes in northwest Greece, vol. 2: Klithi in its local and regional setting*, 441-57. Cambridge: McDonald Institute for Archaeological Research
- Greenland Ice-core Project Members (GRIP) 1993. Climate instability during the last interglacial period recorded in the GRIP ice core. *Nature* 364, 203-7
- Grove, A.T. and Rackham, O. 2001. *The Nature of Mediterranean Europe: An Ecological History*. New Haven and London: Yale University Press
- Grün, R. 1996. A re-analysis of electron spin resonance dating results associated with the Petralona hominid. *Journal of Human Evolution* 30, 227-41
- Guadelli, J.-L., Sirakov, N., Ivanova, St., Sirakova, Sv., Anastassova, E., Courtaud, P., Dimitrova, I., Djabaraska, N., Fernandez, P., Ferrier, C., Fortugne, M., Gambier, D., Guadelli, A., Iordanova, D., Iordanova, N., Kovatcheva, M., Krumov, I., Leblanc, J.-C., Mallye, J.-B., Marinska, M., Miteva, V., Popov, V., Spassov, R., Taneva, St., Tisterat-Laborde, N. and Tsatsova, T. 2005. Une séquence du Paléolithique inférieur au Paléolithique récent dans les Balkans: La Grotte Kozarnika a Orechets (Nord-Ouest de la Bulgarie). In N. Molines, M.-H. Moncel and J.-L. Monnier (eds), *Les Premiers peuplements en Europe*, 87-107. Oxford: British Archaeological Reports International Series 1364
- Güleç, E., White, T., Kuhn, S., Özer, I., Sağır, M., Yılmaz, H. and Howell, F.C. 2009. The Lower Pleistocene lithic assemblage from Dursunlu (Konya), central Anatolia, Turkey. *Antiquity* 83, 11-22
- Hanja, N.Z., Mihevc, A., Pruner, P. and Bosák, P. 2010. Palaeomagnetic research on karst sediments in Slovakia. *International Journal of Speleology* 39 (2), 47-60
- Harden, J.W. 1982. A quantitative index of soil development from field: examples from a chronosequences in Central California. *Geoderma* 285, 1-98
- Harris, D.R. and Vita-Finzi, C. 1968. Kokkinopilos: a Greek badland. *The Geographical Journal* 134 (4), 537-46
- Harvati, K. 2000. Apidima. In E. Delson, I. Tattersall, J.A. van Couvering and A.S Brooks (eds) *Encyclopedia of Human Evolution and Prehistory*, 141-2. New York: Garland Publishing, 2nd edition
- Harvati, K. 2009. Petralona: link between Africa and Europe? In L. Schepartz, S. Fox and C. Bourbou (eds.), *New directions in the skeletal biology of Greece*, 31-48. Athens: Occasional Wiener Laboratory Series, ASCSA
- Harvati, K. and Delson, E. 1999. Conference report: Paleoanthropology of the Mani Peninsula (Greece). *Journal of Human Evolution* 36, 343-8
- Harvati, K., Panagopoulou, E. and Karkanas, P. 2003. First Neanderthal remains from Greece: the evidence from Lakonis. *Journal of Human Evolution* 45, 465-73
- Harvati, K., Panagopoulou, E., Karkanas, P., Athanassiou, A. and Frost, S.R. 2008. Preliminary results of the Aliakmon Paleolithic/Paleoanthropological survey, Greece, 2004-2005. In A. Darlas and D. Mihailović (eds), *The Palaeolithic of the Balkans. Proceedings of the XV World Congress of the IUPPS (Lisbon, 4-9 September 2006)*, 15-20. Oxford: British Archaeological Report 1819
- Harvati, K., Panagopoulou, E. and Runnels, C. 2009. The paleoanthropology of Greece. *Evolutionary Anthropology* 18, 131-43
- Harvati, K., Symeonidis, N. and Doukas, C. n.d. The human upper molar from Megalopolis (*in preparation*)
- Harvey, A.M. 2001. Coupling between hillslopes and channels in upland fluvial systems: implications for landscape sensitivity, illustrated from the Howgill Fells, northwest England. *Catena* 42, 225-50
- Harvey, A.M. 2002. Effective timescales of coupling within fluvial systems. *Geomorphology* 44, 175-201
- Head, M.J. and Gibbard, P.L. 2005. Early-Middle Pleistocene transitions: an overview and recommendation for defining the boundary. In M. Head and P.L. Gibbard (eds), *Early-Middle Pleistocene transitions: the land-ocean evidence*, 1-18. London: Geological Society Special Publications 247
- Heimsath, A.M. and Ehlers, T.A. 2005. Quantifying rates and timescales of geomorphic processes. *Earth Surface Processes and Landforms* 30, 917- 21
- Helmke, J.P., Bauch, H.A., Röhl, U. and Kandiano, E.S. 2008. Uniform climate development between the subtropical and subpolar Northeast Atlantic across marine isotope stage 11. *Climate of the Past* 4, 181-90
- Hennig, G.J., Herr, W., Weber, E. and Xiriotiris, N.I. 1981. ESR-dating of the fossil hominid cranium from Petralona Cave, Greece. *Nature* 292, 533-6
- Hewitt, G. 2000. The genetic legacy of the Quaternary ice ages. *Nature* 405, 907-13
- Higgins, M.D. and Higgins, R. 1996. *A geological companion to Greece and the Aegean*. New York: Cornell University Press

- Higgs, E.S. 1963. A Middle Palaeolithic industry in Greece: Preliminary Report. *Man* 63, 2-3
- Higgs, E.S. 1964. A hand axe from Greece. *Antiquity* 38, 54-5
- Higgs, E.S. and Vita-Finzi, C. 1966. The climate, environment and industries of Stone Age Greece: Part II. *Proceedings of the Prehistoric Society* 32, 1-29
- Hopkinson, T. 2007. The transition from the Lower to the Middle Palaeolithic in Europe and the incorporation of difference. *Antiquity* 81, 294-307
- Horton, R.E. 1945. Erosional development of streams and their drainage basins: hydro-physic approach to quantitative morphology. *Bulletin of the Geological Society of America* 56, 275-370
- Hosfield, R. 2007. Terrestrial implications for the maritime geoarchaeological resource: a view from the Lower Palaeolithic. *Journal of Maritime Archaeology* 2, 4-23
- Hosfield, R.T. and Chambers, J.C. 2004. *The archaeological potential of secondary contexts*. English Heritage Project Report (Project no. 3361), London: English Heritage Archive Report
- Hosfield, R.T. and J.C. Chambers 2005. Pleistocene geochronologies for fluvial sedimentary sequences: an archaeologist's perspective. *Journal of Quaternary Science* 20 (3), 285-96
- Hublin, J.-J. 2002. Glacial/Interglacial cycles and the biological evolution of the Pleistocene peopling of Europe. In A. Tuffreau and W. Roebroeks (eds.) *Le dernier Interglaciaire et les occupations humaines du Paléolithique moyen*, CERP vol. 8, 9-14. Villeneuve d'Ascq: University of Lille
- Hublin, J.-J. 2009. The origin of Neanderthals. *Proceedings of the National Academy of Sciences (USA)* 106 (38), 16022-27
- Huggett, R.J. 2003. *Fundamentals of Geomorphology*. London: Routledge
- Hughes, J.K., Haywood, A., Mithen, S.J., Sellwood, B.W. and Valdes, P.J. 2007a. Investigating early hominin dispersal patterns: developing a framework for climate data integration. *Journal of Human Evolution* 53, 465-74
- Hughes, P.D., Gibbard, P.L. and Woodward, J.C. 2003. Relict rock glaciers as indicators of Mediterranean palaeoclimate during the Last Glacial Maximum (Late Würmian) in northwest Greece. *Journal of Quaternary Science* 18 (5), 431-40
- Hughes, P.D. and Woodward, J.C. 2008. Timing of glaciation in the Mediterranean mountains during the last cold stage. *Journal of Quaternary Science* 23 (6-7), 575-88
- Hughes, P.D., Woodward, J.C. and Gibbard, P.L. 2006a. Late Pleistocene glaciers and climate in the Mediterranean. *Global and Planetary Change* 50, 83-98
- Hughes, P.D., Woodward, J.C. and Gibbard, P.L. 2006b. Quaternary glacial history of the Mediterranean mountains. *Progress in Physical Geography* 30, 334-64
- Hughes, P.D., Woodward, J.C., Gibbard, P.L., Macklin, M. G., Gilmour, M.A. and Smith, G.R. 2006c. The Glacial History of the Pindus Mountains, Greece. *The Journal of Geology* 114, 413-34
- Hughes, P.D., Woodward, J.C. and Gibbard, P.L. 2007b. Middle Pleistocene cold stage climates in the Mediterranean: new evidence from the glacial record. *Earth and Planetary Science Letters* 253, 50-6
- Huxtable, J., Gowlett, J.A.J., Bailey, G.N., Carter, P.L. and Papakonstantinou V. 1992. Thermoluminescence dates and a new analysis of the early Mousterian from Asprochaliko. *Current Anthropology* 33 (1), 109-13
- Huyberts, P. 2007. Glacial variability over the last two million years: an extended depth-derived age model, continuous obliquity pacing, and the Pleistocene progression. *Quaternary Science Reviews* 26, 37-55
- Imeson, A.C. 1986. An eco-geomorphological approach to the soil degradation and erosion problem. In R. Fantechi and N.S. Margaris (eds), *Desertification in Europe: Proceedings of the Information Symposium in the EEC Programme on Climatology, Mytilene, Greece, 1984*, 110-125. Dordrecht: Reidel Publishing
- Imeson, A.C. and Lavee, H. 1998. Soil erosion and climate change: the transect approach and the influence of scale. *Geomorphology* 23, 219-27
- Inbar, M. 1992. Rates of fluvial erosion in basins with a Mediterranean type climate. *Catena* 19, 393-409
- Jackson, J.A. 1994. Active tectonics of the Aegean region. *Annual Review of Earth and Planetary Sciences* 22, 239-71
- Jackson, J.A., King, G. and Vita-Finzi, C. 1982. The neotectonics of the Aegean: an alternative view. *Earth and Planetary Science Letters* 61, 303-18
- Jaeger, J.-J. 1975. The mammalian faunas and hominid fossils of the Middle Pleistocene of the Maghreb. In K. Butzer and G. Isaac (eds), *After the Australopithecines: stratigraphy, ecology, and culture change in the Middle Pleistocene*, 399-418. The Hague: Mouton
- Jahns, S. 2005. The Holocene history of vegetation and settlement at the coastal site of Lake Voulkaria in Acarnania, western Greece. *Vegetation, History and Archaeobotany* 14, 55-66
- Jalut, G., Deboubat, J.J., Fontugne, M. and Otto, T. 2009. Holocene circum-Mediterranean vegetation changes:

- climate forcing and human impact. *Quaternary International* 200, 4-18
- James, P.A., Mee, C.B. and Taylor, G.J. 1994. Soil erosion and the archaeological landscape of Methana, Greece. *Journal of Field Archaeology* 21, 395-416
- Jiménez-Hornero, J., Laguna, A. and Giráldez, J.V. 2005. Evaluation of linear and nonlinear sediment transport equations using hillslope morphology. *Catena* 64, 272-80
- Jiongxin, X. 2005. Precipitation-vegetation coupling and its influence on erosion on the Loess Plateau, China. *Catena* 64, 103-16
- Joannin, S., Quillévère, F., Suc, J.-P., Lécuyer, C. and Martineau, F. 2007. Early Pleistocene climate changes in the central Mediterranean region as inferred from integrated pollen and planktonic foraminiferal stable isotope analyses. *Quaternary International* 67, 264-74
- Jolivet, L. and Brun, J.-P. 2010. Cenozoic geodynamic evolution of the Aegean. *International Journal of Earth Sciences (Geologische Rundschau)* 99, 109-138
- Joordens, J.C.A., Wesselingh, F.P., de Vos, J., Vonhof, H. B. and Kroon, D. 2009. Relevance of aquatic environments for hominins: a case study from Trinil (Java, Indonesia). *Journal of Human Evolution* 57, 656-71
- Kappelman, J., Alçiçek, M.C., Kazanci, N., Schultz, M., ozkul, M. and Şen, S. 2008. First *Homo erectus* from Turkey and implications for migrations into temperate Eurasia. *American Journal of Physical Anthropology* 135, 110-6
- Kapsimalis, V., Pavlakis, P., Poulos, S.E., Alexandri, S., Tziavos, C. Sioulas, A., Filippas, D. and Lykousis, V. 2005. Internal structure and evolution of the Late Quaternary sequence in a shallow embayment: the Amvrakikos Gulf, NW Greece. *Marine Geology* 222-223, 399-418
- Kapsimalis, V., Pavlopoulos, K., Panagiotopoulos, I., Drakopoulou, P., Vandarakis, D., Sakelariou, D. and Anagnostou, C. 2009. Geoarchaeological challenges in the Cyclades continental shelf (Aegean Sea). *Zeitschrift für Geomorphologie* 53, 169-90
- Karkanas, P. 2001. Site formation processes in Theopetra Cave: a record of climatic change during the Late Pleistocene and Early Holocene in Thessaly, Greece. *Geoarchaeology* 16 (4), 373-99
- Karkanas, P. 2002. Micromorphological studies of Greek prehistoric sites: new insights in the interpretation of the archaeological record. *Geoarchaeology* 17, 237-59
- Karkanas P., Panagopoulou E., Anoussis J. and Kyparissi-Apostolika, N. 2008. Raw material procurement in the Middle Palaeolithic of Thessaly: sourcing studies. In Y. Facorellis, N. Zacharias and K. Polikreti (eds), *Proceedings of the 4th Symposium of the Hellenic Society of Archaeometry*, 389-97. Oxford: British Archaeological Report S1746
- Kavvadias, G. 1984. *Palaeolithic Kephallonia: the Fiscardo Culture*. Athens: Filtrakis (in Greek)
- Keraudren, B. and Sorel, D. 1987. The terraces of Corinth (Greece) –a detailed record of eustatic sea-level variations during the last 500,000 years. *Marine Geology* 77, 99-107
- King, G. and Bailey, G. 1985. The palaeoenvironment of some archaeological sites in Greece: the influence of accumulated uplift in a seismically active region. *Proceedings of the Prehistoric Society* 51, 273-82
- King, G., Sturdy, D. and Whitney, J. 1993. The landscape geometry and active tectonics of northwest Greece. *Geological Society of America Bulletin* 105, 137-61
- Kirchner, J.W., Finkel, R.C., Riebe, C.S., Granger, D.E., Clayton, J.L., King, J.G. and Megahan, W.F. 2001. Mountain erosion over 10 yr, 10 k.y., and 10 m.y. time scales. *Geological Society of America* 29 (7), 591-94
- Kirkby, M.J. 1971. Hillslope process-response models based on the continuity equation. In D. Brunnsden (ed.), *Slopes: Form and Process*, 15-30. Institute of British Geographers Special Publications vol. 3
- Kirkby, M. 1999. Regional Desertification Indicators (RDIs). In C. Kosmas, M. Kirkby and N. Geeson (eds), *The Medalus Project: Mediterranean desertification and land use: Manual on key indicators of desertification and mapping environmentally sensitive areas to desertification*, 48-65. European Union 18882
- Kirkby, A. and Kirkby, M.J. 1976. Geomorphic processes and the surface survey of archaeological sites in semi-arid areas. In D.A. Davidson and M.L. Shackley (eds), *Geoarchaeology: Earth Sciences and the Past*, 229-54. London: Duckworth
- Klein, R.G. 2000. Archaeology and the evolution of human behavior. *Evolutionary Anthropology* 9 (1), 17-36
- Klein, R.G. 2009. *The Human Career: human biological and cultural origins*. Chicago: University of Chicago Press, third edition
- Kopaka, K. and Matzanas, C. 2009. Palaeolithic industries from the island of Gavdos, near neighbour to Crete in Greece. *Antiquity* 83 (321) Project Gallery (available at <http://antiquity.ac.uk/projgall/kopaka321/index.html>)
- Korup, O., Clague, J.J., Hermanns, R.L., Hewitt, K., Strom, A.L. and Weidinger, J. 2007. Giant landslides, topography and erosion. *Earth and Planetary Science Letters* 261, 578-89

- Kosmas, C.S., Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., Farand, R., Gutierrez, L., Jacob, A., Marques, H., Martínez-Fernandez, J., Mizara, A., Moustakas, N., Nicolau, J.M., Oliveros, C., Pinna, G., Puddu, R., Puigdefabregas, J., Roxo, M., Simao, A., Stamou, G., Tomasi, N. and Vacca, A. 1997. The effect of land use on runoff and soil erosion rates under Mediterranean conditions. *Catena* 29, 45-59
- Kosmas, C.S., Danalatos, N.G. and Gerontidis, St. 2000. The effect of land parameters on vegetation performance and degree of erosion under Mediterranean conditions. *Catena* 40, 3-17
- Kosmas, C.S., Danalatos, N.G., López-Bermúdez, F. and Romero-Díaz, M.A. 2002. The effect of land use on soil erosion and land degradation under Mediterranean conditions. In N.A. Geeson, C.J. Brandt and J.B. Thornes (eds), *Mediterranean desertification: a mosaic of processes and responses*, 57-70. Chichester: John Wiley & Sons
- Kosmas, C.S., Danalatos, N.G. and Mizara, A. 1998a. Greece. In A.J. Conacher and M. Sala (eds), *Land degradation in Mediterranean environments of the world: nature and extent, causes and solutions*, 67-77. Chichester: John Wiley & Sons
- Kosmas, C.S., Danalatos, N.G. and Mizara, A. 1998b. The causes of land degradation: climate: Greece. In A.J. Conacher and M. Sala (eds), *Land degradation in Mediterranean environments of the world: nature and extent, causes and solutions*, 269-72. Chichester: John Wiley & Sons
- Kosmas C.S., Ferrara, A., Briassouli, H. and Imeson, A. 1999a. Methodology for mapping Environmentally Sensitive Areas (ESAs) to Desertification. In C. Kosmas, M. Kirkby and N. Geeson (eds), *The Medalus Project. Mediterranean desertification and land use: manual on key indicators of desertification and mapping environmentally sensitive areas to desertification*, 31-47. European Union, dir. 18882
- Kosmas, C.S., Poesen, J. and Briassouli, H. 1999b. Key indicators of desertification at the ESA scale. In C. Kosmas, M. Kirkby and N. Geeson (eds), *The Medalus Project. Mediterranean desertification and land use: manual on key indicators of desertification and mapping environmentally sensitive areas to desertification*, 11-30. European Union, dir. 18882
- Kostopoulos, D.S., Palombo, M.-T. and Valli, A.M.F. 2007. Pliocene to Pleistocene large mammal diversity and turnover in North Mediterranean region: the Greek Peninsula with respect to the Iberian and Italian ones. *Geodiversitas* 29 (3), 401-19
- Kostopoulos, D.S., Vassiliadou, K. and Koufos, G.D. 2002. The beginning of Pleistocene in the Balkan area according to the mammal record; palaeozoogeographical approach. *Annales Géologiques des Pays Helléniques* 39A, 253-78
- Kotsakis, K. 1991. The powerful past: theoretical trends in Greek archaeology. In I. Hodder (ed.), *Archaeological Theory in Europe*, 65-90. London: Routledge
- Kotthoff, U., Müller, U.C., Pross, J., Schmiedl, G., Lawson, I.T., van de Schootbrugge, B. and Schulz, H. 2008. Lateglacial and Holocene vegetation dynamics in the Aegean region: an integrated view based on pollen data from marine and terrestrial archives. *The Holocene* 18 (7), 1019-32
- Koufos, G.D. 2001. The Villafranchian mammalian faunas and biochronology of Greece. *Bolletino della Società Paleontologica Italiana* 40 (2), 217-23
- Koufos, G.D. 2009. The Neogene cercopithecids (Mammalia, Primates) of Greece. *Geodiversitas* 31 (4), 817-50
- Koufos, G.D. and de Bonis, L. 2004. The deciduous lower dentition of *Ouranopithecus macedoniensis* (Primates, Hominoidea) from the late Miocene deposits of Macedonia, Greece. *Journal of Human Evolution* 46, 699-718
- Koufos, G.D., Kostopoulos, D. and Vlachou, T. 2005. Neogene/Quaternary mammalian migrations in Eastern Mediterranean. *Belgian Journal of Zoology* 135 (2) 181-190
- Koufos, G.D., Syrides, G.E., Kostopoulos, D.S. and Koliadimou, K.K. 1995. Preliminary results about the stratigraphy and the palaeoenvironment of Mygdonia Basin, Macedonia, Greece. *Geobios* 18, 243-9
- Koukis, G., Sabatakakis, N., Ferentinou, M., Lainas, S., Alexiadou, X. and Panagopoulos, A. 2009. Landslide phenomena related to major fault tectonics: rift zone of Corinth Gulf, Greece. *Bulletin of the Engineering Geology and the Environment* 68, 215-29
- Koukis, G. and Ziourkas, C. 1991. Slope instability phenomena in Greece: a statistical analysis. *Bulletin of the International Association of Engineering Geology* 43, 47-60
- Koulouri, M. and Giourga C. 2007. Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands. *Catena* 69, 274-81
- Koumouzelis, M., Ginter, B., Kozłowski, J.K., Pawlikowski, M., Bar-Yosef, O., Albert, R.M., Litynska-Zajac, M., Stworzewicz, E., Wojtal, P., Lipecki, G., Tomek, T. and Bochenki, Z.M. 2001. The Early Upper Palaeolithic in Greece: the excavations in Klisoura Cave. *Journal of Archaeological Science* 28, 515-39
- Kourtessi-Philippakis, G. 1986. *Le Paléolithique de la Grèce Continentale. État de la Question et Perspectives de Recherche*. Paris: Publications de la Sorbonne

- Kourtesi-Philippakis, G. 1999. The Lower and Middle Palaeolithic in the Ionian Islands: new finds. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic archaeology of Greece and adjacent areas: Proceedings of the ICOPAG conference, Ioannina*, 282-87. London: British School at Athens Studies 3
- Kraft, J.C., Aschnebrenner, E.S. and Rapp, G.Jr. 1977. Palaeogeographic reconstructions of coastal Aegean archaeological sites. *Science* 195, 941-47
- Krahtopoulou, A. and Frederick, C. 2008. The stratigraphic implications of long-term terrace agriculture in dynamic landscapes: polycyclic terracing from Kythera Island, Greece. *Geoarchaeology* 23 (4), 550-85
- Kretzoi, M. and Poulanos, A.N. 1981. Remarks on the Middle and Lower Pleistocene vertebrate fauna in the Petralona Cave (with special reference to new microfauna – up to 1981). *Anthropos* 8, 57-72
- Ku, T.L. and Liang, Z.C. 1983. The dating of impure carbonates with decay series isotopes. *Proceedings of the Seminar on Alpha Particle Spectrometry and Low Level Measurement*, 563-71. England: Harwell
- Kuhn, S.L. 1991. “Unpacking” reduction: lithic raw material economy in the Mousterian of west-central Italy. *Journal of Anthropological Archaeology* 10, 76-106
- Kuhn, S.L. 1995. *Mousterian lithic technology: an ecological perspective*. Princeton: Princeton University Press
- Kuhn, S. 2002. Paleolithic Archaeology in Turkey. *Evolutionary Anthropology* 11, 198-210
- Kuhn, S. 2010. Was Anatolia a bridge or a barrier to early hominin dispersals? *Quaternary International* 223-224, 434-5
- Kuhn, S., Arsebük, G. and Howell, F.C. 1996. The Middle Pleistocene lithic assemblage from Yarımburgaz Cave, Turkey. *Paléorient* 22 (1) 31-49
- Kukla, G.J., Bender, M.L., de Beaulieu, J.-L., Bond, G., Broecker, W.S., Cleveringa, P., Gavin, J.E., Herbert, T. D., Imbrie, J., Jouzel, J., Keigwin, L.D., Knudsen, K.-L., McManus, J.F., Merkt, J., Muhs, D.R., Müller, H., Poore, R.Z., Porter, S.C., Seret, G., Shackleton, N., Turner, C., Tzedakis P.C. and Winograd, I.J. 2002. Last Interglacial Climates. *Quaternary Research* 58, 2-13
- Kurtén, B. and Poulanos, A.N. 1977. New stratigraphic and faunal material from Petralona cave, with special reference to the Carnivora. *Anthropos* (Athens) 4, 47-130
- Kuzman, P. 1993. The Palaeolithic in Macedonia. *Macedonia Acta Archaeologica* 13, 9-16
- Kyparissi-Apostolika, N. (ed.) 2000. *Theopetra Cave: Twelve years of excavation and research 1987-1998. Proceedings of the International Conference, Trikala (6-7 November 1998)*. Athens: Greek Ministry of Culture and Institute for Aegean Prehistory
- Lagios, E., Sakkas, V., Papadimitriou, P., Parcharidis, I., Damiata, B.N., Chousianitis, K. and Vassilopoulou, S. 2007. Crustal deformation in the Central Ionian Islands (Greece): results from DGPS and DInSAR analyses (1995-2006). *Tectonophysics* 444, 119-45
- Lambeck, K. 1995. Late Pleistocene and Holocene sea-level change in Greece and south-western Turkey: a separation of eustatic, isostatic and tectonic contributions. *Geophysical Journal International* 122, 1022-44
- Lambeck, K. 1996. Sea-level change and shore-line evolution in Aegean Greece since Upper Palaeolithic time. *Antiquity* 70, 588-611
- Lambeck, K. 2004. Sea-level change through the last glacial cycle: geophysical, glaciological and palaeogeographic consequences. *Comptes Rendus Geoscience* 336, 677-89
- Lambeck, K., Esat, E.M. and Potter, E.-K. 2002a. Links between climate and sea levels for the past three million years. *Nature* 419, 199-206
- Lambeck, K. and Purcell, A. 2005. Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. *Quaternary Science Reviews* 24, 1969-88
- Lambeck, K., Yokoyama, Y. and Purcell, T. 2002b. Into and out of the Last Glacial Maximum: sea-level change during Oxygen Isotope Stages 3 and 2. *Quaternary Science Reviews* 21, 343-60
- Langbein, W.B. and Schumm, S.A. 1958. Yield of sediment in relation to mean annual precipitation. *Transactions of the American Geophysical Union* 39, 1076-84
- Latham, A.G. and Swarcz, H.P. 1992. The Petralona hominid site: Uranium-series re-analysis of ‘Layer 10’ calcite and associated palaeomagnetic analyses. *Archaeometry* 34 (1), 135-40
- Laukhin, S.A., Ranov, V.A. and Volgina, V.A. 2007. The correlation between hamra and the Palaeolithic on the coastal plain of the southern Levant. *Geoarchaeology* 22, 641-51
- Lavee, H., Imeson, A.C. and Sarah, P. 1998. The impact of climate change on geomorphology and desertification along a mediterranean-arid transect. *Land degradation and development* 9, 407-22
- Leeder, M.R. 1991. Denudation, vertical crustal movements and sedimentary basin infill. *Geologische Rundschau* 80 (2) 441-58

- Leeder, M.R. 1997. Sedimentary basins: tectonic recorders of sediment discharge from drainage catchments. *Earth Surface Processes and Landforms* 22, 297-37
- Leeder, M.R., Collier, R.E.L., Abdul Aziz, H.A., Trout, M., Ferentinos, G., Papatheodorou, G. and Lyberis, E. 2002. Tectono-sedimentary processes along an active marine/lacustrine half graben margin: Alkyonides Gulf, E. Gulf of Corinth, Greece. *Basin Research* 14, 25-41
- Leeder, M.R., Harris, T. and Kirkby, M.J. 1998. Sediment supply and climate change: implications for basin stratigraphy. *Basin Research* 10, 7-18
- Leeder, M.R. and Jackson, J.A. 1993. The interaction between normal faulting and drainage in active extensional basins, with examples from the western United States and central Greece. *Basin Research* 5, 79-102
- Leeder, M.R., Mark, G.H., Brasier, A.T., Parrish, R.R., McIntosh, W.C., Andrews, J.E. and Duermeijer, C.E. 2008. Late-Pliocene timing of Corinth (Greece) rift-margin fault migration. *Earth and Planetary Science Letters* 274, 132-41
- Lefevre, D. and Raynal J.-P. 2002. Les formations plio-pléistocènes de Casablanca et la chronostratigraphie du Quaternaire marin du Maroc revisitées. *Quaternaire* 13 (1), 9-21
- Le Pichon, X. and Angelier, J. 1979. The Hellenic arc and trench system: a key to the neotectonic evolution of the Eastern Mediterranean area. *Tectonophysics* 60, 1-42
- Leroi-Gourhan, A. 1964. Découvertes paléolithiques en Élide. *Bulletin de la Correspondance Hellénique* 88, 1-8
- Lespez, L. 2003. Geomorphic responses to long-term land use changes in Eastern Macedonia. *Catena* 51, 181-208
- Lewin, J., Macklin, M.G. and Woodward, J.C. 1991. Late Quaternary fluvial sedimentation in the Voidomatis Basin, Epirus, Northwest Greece. *Quaternary Research* 35, 103-15
- Lindsay, E. 1997. Eurasian mammal biochronology: an overview. *Palaeogeography, Palaeoclimatology, Palaeoecology* 133, 117-28
- Lister, A.M., Sher, A.V., van Essen, H. and Wei, G. 2005. The pattern and process of mammoth evolution in Eurasia. *Quaternary International* 126-128, 49-64
- Liu, Q.-Q., Chen, L. and Li, J.-C. 2001. Influences of slope gradient on soil erosion. *Applied Mathematics and Mechanics* 22 (5), 510-19
- Loarie, S.R., Duffy, P.B., Hamilton, H., Asner, G.P., Field, C.B. and Ackerly, D.D. 2009. The velocity of climate change. *Nature* 462, 1052-57
- López Antoñanzas, R. and Cuenca Bescós, G. 2002. The Gran Dolina site (Lower to Middle Pleistocene, Atapuerca, Burgos, Spain): new palaeoenvironmental data based on the distribution of small mammals. *Palaeogeography, Palaeoclimatology, Palaeoecology* 186, 311-34
- López-Bermudez, F., Romero-Díaz, A., Martínez-Fernández, J. and Martínez-Fernández, J. 1998. Vegetation and soil erosion under a semi-arid Mediterranean climate: a case study from Murcia (Spain). *Geomorphology* 24, 51-8
- Loutre, M.F. and Berger, A. 2003. Marine Isotope Stage 11 as an analogue for the present interglacial. *Global and Planetary Change* 36, 209-17
- Lykousis, V. 2001. Subaqueous bedforms on the Cyclades Plateau (NE Mediterranean) – evidence of Cretan Deep Water Formation? *Continental Shelf Research* 21, 495-507
- Lykousis, V. 2009. Sea-level changes and shelf break prograding sequences during the last 400 ka in the Aegean margins: subsidence rates and palaeogeographic implications. *Continental Shelf Research* 29, 2037-44
- Lykousis, V., Anagnostou, C., Pavlakis, P., Rousakis, G. and Alexandri, M. 1995. Quaternary sedimentary history and neotectonic evolution of the eastern part of Central Aegean Sea, Greece. *Marine Geology* 128, 59-71
- Lykousis, V., Karageorgis, A.P. and Chronis, G.T. 2005. Delta progradation and sediment fluxes since the last glacial in the Thermaikos Gulf and the Sporades Basin, NW Aegean Sea, Greece. *Marine Geology* 222-223, 381-97
- Lykousis, V., Roussakis, G., Alexandri, M., Pavlakis, P. and Papoulia, I. 2002. Sliding and regional slope stability in active margins: North Aegean Trough (Mediterranean). *Marine Geology* 186, 281-98
- Lykousis, V., Roussakis, G. and Sakellariou, D. 2009. Slope failures and stability analysis of shallow water prodeltas in the active margins of Western Greece, northeastern Mediterranean Sea. *International Journal of Earth Sciences (Geologische Rundschau)* 98, 807-22
- Lykousis, V., Sakellariou, D., Moretti, I. and Kaberi, H. 2007. Late Quaternary basin evolution of the Gulf of Corinth: Sequence stratigraphy, sedimentation, fault-slip and subsidence rates. *Tectonophysics* 440, 29-51
- Macklin, M.G., Fuller, I.C., Lewin, J., Maas, G.S., Passmore, D.G., Rose, J., Woodward, J.C., Black, S., Hamlin, R.H.B. and Rowan, J.S. 2002. Correlation of fluvial sequences in the Mediterranean basin over the last 200 ka and their relationship to climate change. *Quaternary Science Reviews* 21, 1633-41

- Macklin, M.G., Lewin, J. and Woodward, J.C. 1995. Quaternary fluvial systems in the Mediterranean basin. In J. Lewin, M.G. Macklin and J.C. Woodward (eds), *Mediterranean Quaternary River Environments*, 1-25. Rotterdam: Balkema
- Magaldi, D. and Tallini, M. 2000. A micromorphological index of soil development for the Quaternary geology research. *Catena* 41, 261-76
- Magri, D. and Tzedakis, P.C. 2000. Orbital signatures and long-term vegetation patterns in the Mediterranean. *Quaternary International* 73/74, 69-78
- Mallegni, F., 2006. The Ceprano skull and the earliest peopling of Europe: overview and perspectives. *Human Evolution* 21, 261-8
- Manolis, S., Aiello, L., Hennessy, R. and Kyparissi-Apostolika, N. 2000. The Middle Palaeolithic footprints from Theopetra Cave. In N. Kyparissi-Apostolika (ed.), *Theopetra Cave: Twelve years of excavation and research 1987-1998. Proceedings of the International Conference, Trikala (6-7 November 1998)*, 81-93. Athens: Greek Ministry of Culture and Institute for Aegean Prehistory
- Manzi, G. 2004. Human evolution at the Matuyama-Bruhnes boundary. *Evolutionary Anthropology* 13, 11-24
- Marean, C.W., Bar-Matthews, M., Bematchez, J., Fisher, E., Goldberg, P., Herries, A.R., Jacobs, Z., Jerardino, A., Karkanas, P., Minichillo, T., Nilssen, P., Thompson, E., Watts, I. and Williams, H.M. 2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature* 449, 905-9
- Mariolakos, I., Badekas, I., Fountoulis, I. and Theocharis, D. 1994. Reconstruction of the Early Pleistocene paleoshore and paleorelief of SW Peloponnesus area. 7th Congress of the Geological Society of Greece, May 1994, *Bulletin of the Geological Society of Greece* XXX (2), 279-304
- Martin, Y. and Church, M. 1997. Diffusion in landscape development models: on the nature of basic transport relations. *Earth Surface Processes and Landforms* 22, 273-79
- Martínez-Navarro, B., Belmaker, M. and Bar-Yosef, O. 2009. The large carnivores from 'Ubeidiya (early Pleistocene, Israel): biochronological and biogeographical implications. *Journal of Human Evolution* 56, 514-24
- Martínez -Navarro B. and Palmqvist P. 1996. Presence of the African saber-toothed felid *Megantereon whitei* (Broom, 1937) (Mammalia, Carnivora, Machairodontinae) in Apollonia-1 (Mygdonia Basin, Greece). *Journal of Archaeological Science* 23, 869-72
- Martínez-Navarro, B., Palmqvist, P., Shabel A.B., Perez-Claros, J.A., Lorenzo, C. and Claret, A. 2008. Reply to Gibert *et al.* (2008) on the supposed human phalanx from Cueva Victoria (Cartagena, Spain). *Journal of Human Evolution* 54, 157-61
- Martínez-Navarro, B., Turq, A., Agustí Ballester, J. and Oms, O. 1997. Fuente Nueva-3 (Orce, Granada, Spain) and the first human occupation of Europe. *Journal of Human Evolution* 33, 611-20
- Martini, I.P. and Sagri, M. 1993. Tecto-sedimentary characteristics of Late Miocene-Quaternary extensional basins of the Northern Apennines, Italy. *Earth-Science Reviews* 34, 197-233
- Martinón-Torres, M., Bermúdez de Castro, J.M., Gómez-Robles, A., Arsuaga, J.L., Carbonell, E., Lordkipanidze, D., Manzi, G. and Margvelashvili, A. 2007. Dental evidence on the hominin dispersals during the Pleistocene. *Proceedings of the National Academy of Sciences (USA)* 104 (33), 13279-82
- Martinón-Torres, M., Bermúdez de Castro, J.M., Gómez-Robles, A., Margvelashvili, A., Prado, L., Lordkipanidze, D. and Vekua, A. 2008. Dental remains from Dmanisi (Republic of Georgia): morphological analysis and comparative study. *Journal of Human Evolution* 55, 249-73
- Mascle, J. and Martin, L. 1990. Shallow structure and recent evolution of the Aegean Sea: a synthesis based on continuous reflection profiles. *Marine Geology* 94, 271-99
- Maslin, M.A. and Ridgwell, A.J. 2005. Mid-Pleistocene revolution and the "eccentricity myth". In M.J. Head and P.L. Gibbard (eds), *Early-Middle Pleistocene Transitions: the Land-Ocean Evidence*, 19-34. London: Geological Society Special Publications 247
- Mather, A.E. 2009. Tectonic setting and landscape development. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 5-32. Oxford: Oxford University Press.
- Mather, A.E., Strokes, M. and Griffiths, J.S. 2002. Quaternary landscape evolution: a framework for understanding contemporary erosion, southeast Spain. *Land degradation and development* 13, 89-109
- Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlen, W., Maasch, K.A., Meeker, L.D., Meyerson, E.A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R. R. and Steig, E.J. 2004. Holocene climate variability. *Quaternary Research* 62, 243-55
- McKenzie, D. 1978. Some remarks on the development of sedimentary basins. *Earth and Planetary Science Letters* 40, 25-32

- McManus, J.F., Oppo, D.W. and Cullen, J.L. 1999. A 0.5-Million-year record of millennial-scale climate variability in the North Atlantic. *Science* 283, 971-75
- McNabb, J. 2005. Hominins and the Early-Middle Pleistocene transition: evolution, culture and climate in Africa and Europe. In M. Head and P.L. Gibbard (eds), *Early-Middle Pleistocene transitions: the land-ocean evidence*, 287-304. London: Geological Society Special Publications 247
- McNabb, J. 2007. *The British Lower Palaeolithic: stones in contention*. London: Routledge
- Médail, F. and Diadema, K. 2009. Glacial refugia influence plant diversity patterns in the Mediterranean Basin. *Journal of Biogeography* 36 (7), 1333-45
- Melentis, J.K. 1961. Studien über fossile Vertebraten Griechenlands: 2. Die Dentition der pleistozänen Proboscider des Beckens von Megalopolis im Peloponnes (Griechenland). *Annales Géologiques des Pays Helléniques* XII, 154-262
- Mendrinou, D., Chorapanitis, I., Polyzou, O. and Karytsas, C. 2010. Exploring for geothermal resources in Greece. *Geothermics* 39, 124-37
- Mercier, J.L., Carey, E., Phillip, H. and Sorel, D. 1976. La néotectonique plio-quaternaire de l'arc égéen externe et de la mer Egée et ses relations avec la sismicité. *Bulletin of the Geological Society of France* XVIII (7), 355-72
- Meulenkamp, J.E. 1985. Aspects of the Late Cenozoic Evolution of the Aegean Region. In D.J. Stanley and F.-C. Wezel (eds), *Geological Evolution of the Mediterranean Basin*, 307-21. New York: Springer-Verlag
- Milliken, S. 1999. The earliest occupation of Italy. *Accordia Research Papers* 7, 7-36
- Milojčić, V., Boessneck, J., Jung, D. and Schneider, H. 1965. *Paläolithikum um Larissa in Thessalien*. Bonn: Rudolf Habelt Verlag.
- Mimikou, M.A. 2005. Water resources in Greece: present and future. *Global NEST Journal* 7 (3), 313-22
- Mishra, S., White, M.J., Beaumont, P., Antoine, P., Bridgeland, D.R., Limondin-Lozouet, N., Santisteban, J.I., Schreve, D.C., Shaw, A.D., Wenban-Smith, F.F., Westaway, R.W.C. and White, T.S. 2007. Fluvial deposits as an archive of early human activity. *Quaternary Science Reviews* 26, 2996-3016
- Monnier, G.F. 2006. The Lower/Middle Palaeolithic periodizations in Western Europe. *Current Anthropology* 47 (5), 709-44
- Montgomery, D.R. 2001. Slope distributions, threshold hillslopes and steady-state topography. *American Journal of Science* 301, 432-54
- Montgomery, D.R. and Brandon, M.T. 2002. Topographic controls on erosion rates in tectonically active mountain ranges. *Earth and Planetary Science Letters* 201, 481-89
- Montgomery, D.R. and Dietrich, W.E. 1992. Channel initiation and the problem of landscape scale. *Science* 255, 826-29
- Morreti, I., Sakellariou, D., Lykousis, V. and Micarelli, L. 2003. The Gulf of Corinth: an active half graben? *Journal of Geodynamics* 36, 323-40
- Morton, A.G.T. 2004. *Archaeological Site formation: Understanding Lake Margin Contexts*. Oxford: British Archaeological Reports International Series 1211
- Morwood, M.J., O'Sullivan, P.B., Aziz, F., Raza, A., 1998. Fission-track ages of stone tools and fossils on the east Indonesian island of Flores. *Nature* 392, 173-76
- Mounier, A., Marschal, F. and Condemi, S. 2009. Is *Homo heidelbergensis* a distinct species? New insight on the Mauer mandible. *Journal of Human Evolution* 56, 219-46
- Mountrakis, D. 1985. *Geology of Greece*. Thessaloniki: University Studio Press (in Greek)
- Mountrakis, D. Synoptic geodynamic evolution of the broader Hellenic region. *University e-notes*, Aristotle University of Thessaloniki, Department of Geology, available at <http://www.geo.auth.gr/courses/ggg/ggg871y/> (in Greek)
- Mulligan, M. 1998. Modeling the geomorphological impact of climate variability and extreme events in a semi-arid environment. *Geomorphology* 24, 59-78
- Mussi, M. 1995. The earliest occupation of Europe: Italy. In W. Roebroeks and T. van Kolfschoten (eds), *The earliest occupation of Europe: Proceedings of the European Science Foundation workshop at Tautavel (France), 1993*, 27-49. Leiden: University of Leiden
- Mussi, M. 1999. The Neanderthals in Italy: a tale of many caves. In W. Roebroeks and C. Gamble (eds), *The Middle Palaeolithic occupation of Europe*, 49-80. Leiden: University of Leiden
- Mussi, M. 2001. *Earliest Italy: an overview of the Italian Palaeolithic and Mesolithic*. New York: Kluwer Academic Publishers
- Muttoni, G., Scardia, G., Kent, D.V., Swisher, C.C. and Manzi, G. 2009. Pleistocene magnetochronology of early hominin sites at Ceprano and Fontana Ranuccio, Italy. *Earth and Planetary Science Letters* 286, 255-68
- Nash, D.T. and Petraglia, M.D. 1987. *Natural Formation Processes and the Archaeological Record*. Oxford: British Archaeological Reports International Series 352
- Ntinou, M. 2000. Preliminary results of charcoal analysis from Theopetra cave. In N. Kyparissi-Apostolika (ed.), *Theopetra Cave: Twelve years of excavation and research 1987-1998. Proceedings of the Interna-*

- tional Conference, Trikala (6-7 November 1998), 76-80. Athens: Greek Ministry of Culture and Institute for Aegean Prehistory
- Okuda, M., van Vugt, N., Nakagawa, T., Ikeya, M., Hayashida, A., Yasuda, Y. and Setoguchi, T. 2002. Palynological evidence for the astronomical origin of lignite-detritus sequence in the Middle Pleistocene Marathousa Member, Megalopolis, SW Greece. *Earth and Planetary Science Letters* 201, 143-57
- Okuda, M., Yasuda, Y. and Setoguchi, T. 2001. Middle to Late Pleistocene vegetation history and climatic changes at Lake Kopais, Southeast Greece. *Boreas* 30, 73-82
- Oms, O., Parés, J.M., Martínez-Navarro, B., Agustí, J., Toro, I., Martínez-Fernandez, G. and Turq, A. 2000. Early human occupation of Western Europe: palaeomagnetic dates for two Palaeolithic sites in Spain. *Proceedings of the National Academy of Science* 97, 10666-70
- Oosterbeek, L., Grimaldi, S., Rosina, P., Cura, S., Pedro, P., Cunha and Martins, A. 2010. The earliest Pleistocene archaeological sites in western Iberia: present evidence and research prospects. *Quaternary International* 223-224, 399-407
- Oppenheimer, S. 2009. The great arc of dispersal of modern humans: Africa to Australia. *Quaternary International* 202 (1-2), 2-13
- Oppo, D.W., McManus, J.F. and Cullen, J.L. 1998. Abrupt climate events 500,000 to 340,000 years ago: evidence from subpolar North Atlantic sediments. *Science* 279, 1335-38
- O'Regan, H.J., Bishop, L.C., Lamb, A.L., Elton, S. and Turner, A. 2005. Large mammal turnover in Africa and the Levant between 1.0 and 0.5 Ma. In M.J. Head and P.L. Gibbard (eds), *Early-Middle Pleistocene transitions: the land-ocean evidence*. Geological Society Special Publication 247, 231-49
- O'Regan, H.J., Turner, A., Bishop, L.C., Elton, S. and Lamb, A.L. in press. Hominins without fellow travelers? First appearances and inferred dispersals of Afro-Eurasian large-mammals in the Plio-Pleistocene. *Quaternary Science Reviews* (2009)
- Otte, M. 2010. Before Levallois. *Quaternary International* 223-224, 273-80
- Otte, M., Yalçinkaya, I., Bar-Yosef, O., Kozłowski, J., Leotard, J.M., Taskiran, H., Noiret, P. and Kartal, M. 1999. The Anatolian Palaeolithic: data and reflections. In G. Bailey, E. Adam, E. Panagopoulou and C. Perlès (eds.), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 73-85. London: British School at Athens Studies 3
- Otte, M., Yalçinkaya, I., Kozłowski, J., Bar-Yosef, O., López Bayón, I. and Taskiran, H. 1998. Long-term technical evolution and human remains in the Anatolian Palaeolithic. *Journal of Human Evolution* 34, 413-31
- Otte, M., Yalçinkaya, I., Taskiran, H., Kozłowski, J., Bar-Yosef, O. and Noiret, P. 1995. The Anatolian Middle Paleolithic: new research at Karain Cave. *Journal of Anthropological Research* 51 (4), 287-99
- Palli, O. and Papadea, A. 2004. Le nouveaux sites paléolithiques en Thesprotie. In P. Cabanes and J.-L. Lamboley (eds), *L'Illyrie Meridionale et l'Épire dans l'Antiquité IV: Actes du IV colloque international de Grenoble (10-12 octobre 2002)*, 17-22. Paris: De Boccard
- Palmqvist, P. 1997. A critical re-evaluation of the evidence for the presence of hominids in Lower Pleistocene times at Venta micena, southern Spain. *Journal of Human Evolution* 33, 83-9
- Palmqvist, P., Martínez-Navarro, B., Toro, I., Patrocínio Espigares, M., Ros-Montoya, S., Torregrosa, V. and Pérez-Claros, J.A. 2005. Réévaluation de la présence humaine au Pléistocène inférieur dans le Sud de l'Espagne. *L'Anthropologie* 109, 411-50
- Palmqvist, P., Pérez-Claros, J.A., Gibert, J. and Santamaria J.L. 1996. Comparative morphometric study of a human phalanx from the Lower Pleistocene site at Cueva Victoria (Murcia, Spain), by means of Fourier analysis, shape coordinates of landmarks, principal and relative warps. *Journal of Archaeological Science* 23, 95-107
- Palombo, M.R. and Ferretti, M.P. 2005. Elephant fossil record from Italy: knowledge, problems and perspectives. *Quaternary International* 126-128, 107-36
- Palombo, M.R. and Mussi, M. 2006. Large mammal guilds at the time of the first human colonization of Europe: the case of the Italian Pleistocene record. *Quaternary International* 149, 94-103
- Palombo, M.R. and Sardella, R. 2007. Biochronology and biochron boundaries: a real dilemma or a false problem? An example based on the Pleistocene large mammalian faunas from Italy. *Quaternary International* 160, 30-42
- Panagopoulou, E. 1999. The Theopetra Middle Palaeolithic assemblages: their relevance to the Middle Palaeolithic of Greece and adjacent areas. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 252-65. London: British School at Athens Studies 3
- Panagopoulou, E., Harvati, K., Karkanas, P., Athanassiou, A., Elefanti, P. and Frost, S.R. 2006. The West

- Macedonia Palaeolithic Survey. *The Archaeological Research in Macedonia and Thrace* 18, 631-40 (in Greek)
- Panagopoulou, E., Karkanias, P., Tsartsidou, G., Harvati, K. and Ntinou, M. 2002-2004. Late Pleistocene archaeological and fossil human evidence from Laconis Cave, southern Greece. *Journal of Field Archaeology* 29 (3-4), 323-49
- Panagopoulou, E., Kotjabopoulou, E. and Karkanias, P. 2001. Geoarchaeological research in Alonnisos: new evidence on the Palaeolithic and Mesolithic in the Aegean region. In A. Sampson (ed.), *The archaeological research in Northern Sporades*, 121-51. Alonnisos: Municipality of Alonnisos (in Greek)
- Papagianni, D. 2000 *Middle Palaeolithic Occupation and Technology in Northwest Greece: The Evidence from Open-Air Sites*. Oxford: British Archaeological Report 882
- Papakonstantinou, V. 1991. Indications of Palaeolithic presence in Aetoloakarnania. *Proceedings of the 1st Archaeological and Historical Conference of Aetoloakarnania*, 23-6, Agrinio (in Greek)
- Papakonstantinou V. and Vassilopoulou, D. 1997. The Middle Palaeolithic industries of Epirus. In G.N. Bailey (ed.), *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece, vol. 2: Klithi in its local and regional setting*, 459-80. Cambridge: McDonald Institute for Archaeological Research
- Papanikolaou, D., Fountoulis, I. and Metaxas, C. 2007. Active faults, deformation rates and Quaternary palaeogeography at Kyparissiakos Gulf (SW Greece) deduced from onshore and offshore data. *Quaternary International* 171-172, 14-30
- Parés, J.M. and Pérez-González, A. 1999. Magnetochronology and stratigraphy at Gran Dolina section, Atapuerca (Burgos, Spain). *Journal of Human Evolution* 37, 325-42
- Parés, J.M., Pérez-González, A., Rosas, A., Benito, A., Bermúdez de Castro, J.M., Carbonell, E. and Huguet, R. 2006. Matuyama-age lithic tools from the Sima del Elefante site, Atapuerca (northern Spain). *Journal of Human Evolution* 50, 163-9
- Parfitt, S.M., Barendregt, R.W., Breda, M., Candy, I., Collins, M., Coope, G.R., Durbidge, P., Field, M.H., Lee, J.R., Liter, A.M., Mutch, R., Penkman, K.E., Preece, R.C., Rose, J., Stringer, C.S., Symmons, R., Whittaker, J.E., Wymer, J.J. and Stuart, A.J. 2005. The earliest record of human activity in northern Europe. *Nature* 438, 1008-12
- Paspallis, D. 2003. *Geomorphometric characteristics of the hydrologic basins of Greece*. Unpublished Bachelor Thesis, Athens: Athens Polytechnic School (in Greek)
- Pavlidis, S.B. and Mountrakis, M. 1987. Extensional tectonics of northwestern Macedonia, Greece, since the late Miocene. *Journal of Structural Geology* 9 (4), 385-92
- Peeters, I., van Oost, K., Govers, G., Verstraeten, G., Rommens, T. and Poesen, J. 2008. The compatibility of erosion data at different temporal scales. *Earth and Planetary Science Letters* 265, 138-52
- Peltier, W.R. 2002. On eustatic sea level history: Last Glacial Maximum to Holocene. *Quaternary Science Reviews* 21, 377-96
- Peretto, C. 2006. The first peopling of southern Europe: the Italian case. *Human Palaeontology and Prehistory* 5, 283-90
- Pérez-Peña, J.V., Azanón, J.M., Azor, A., Tuccimei, P., Della Seta, M. and Soligo, M. 2009. Quaternary landscape evolution and erosion rates for an intra-montane Neogene basin (Guadix-Baza basin, SE Spain). *Geomorphology* 106, 206-18
- Perissoratis, C. and Conispoliatis, N. 2003. The impacts of sea-level changes during latest Pleistocene and Holocene times on the morphology of the Ionian and Aegean Seas (SE Alpine Europe). *Marine Geology* 196, 145-56
- Perissoratis, C. and Mitropoulos, D. 1989. Late Quaternary evolution of the Northern Aegean Shelf. *Quaternary Research* 32, 36-50
- Perissoratis, C., Piper, D.J.W. and Lykousis, V. 2000. Alternating marine and lacustrine sedimentation during late Quaternary in the Gulf of Corinth rift basin, central Greece. *Marine Geology* 167, 391-411
- Perissoratis, C. and van Andel, T.H. 1988. Late Pleistocene unconformity in the Gulf of Kavalla, northern Aegean, Greece. *Marine Geology* 81, 53-61
- Perissoratis, C. and van Andel, T.H. 1991. Sea-level changes and tectonism in the formation of the Quaternary basin of the South Evvoikos Gulf, Greece. *Terra Nova* 3, 294-302
- Petraglia, M.D. and Nash, D.T. 1987. The impact of fluvial processes on experimental sites. In D.T. Nash and M. D. Petraglia (eds), *Natural Formation Processes and the Archaeological Record*. Oxford: British Archaeological Reports International Series 352
- Philippson, A. 1950. *Die Griechischen Landschaften: Band I, Teil I: Thessalien und die Spercheios-Senke*. Frankfurt: V. Klostermann
- Phillips, J.D. 1993. Instability and chaos in hillslope evolution. *American Journal of Science* 293, 25-48
- Phillips, J.D. 1995. Biogeomorphology and landscape evolution: the problem of scale. *Geomorphology* 13, 337-47

- Phillips, J.D. 2003. Alluvial storage and the long-term stability of sediment yields. *Basin research* 15, 153-63
- Phillips, J.D. 2005. Weathering instability and landscape evolution. *Geomorphology* 67, 255-72
- Phillips, J.D. 2006. Evolutionary geomorphology: thresholds and nonlinearity in landform response to environmental change. *Hydrology and Earth System Sciences* 10, 731-42
- Pinet, P. and Souriau, M. 1988. Continental erosion and large-scale relief. *Tectonics* 7, 563-82
- Piper, D.J.W. and Perissoratis, C. 2003. Quaternary neotectonics of the South Aegean arc. *Marine Geology* 198, 259-88
- Pitsios, T.K. 1979. Palaeoanthropological finds of inner-Mani (preliminary report). *Anthropos* 6, 98-105 (in Greek)
- Pitsios, T.K. 1996. The Tainarius Man. *Arxaiologia kai Technes* 60, 68-72 (in Greek)
- Pitsios, T.K. 1999. Paleoanthropological research at the cave site of Apidima and the surrounding region (South Peloponnese, Greece). *Anthropologischer Anzeiger* 57 (1), 1-11
- Poesen, J.W., van Wesemael, B., Bunte, K. and Solé Benet, A. 1998. Variation of rock fragment cover and size along semiarid hillslopes: a case-study from southeast Spain. *Geomorphology* 23, 323-35
- Pollard, D. and Barron, E.J. 2003. Causes of model-data discrepancies in European climate during oxygen isotope stage 3 with insights from the last glacial maximum. *Quaternary Research* 59, 108-13
- Pope, K.O., Runnels, C.N. and Ku, T.-L. 1984. Dating Middle Palaeolithic red beds in southern Greece. *Nature* 312, 264-6
- Pope, K.O. and van Andel, T.H. 1984. Late Quaternary alluviation and soil formation in the southern Argolid: its history, causes and archaeological implications. *Journal of Archaeological Science* 11, 281-306
- Poulianos, A.N. 1980. The postcranial skeleton of the *Archanthropus europaeus petraloniensis*. *Anthropos* (Athens) 7, 13-29 (in Greek)
- Poulianos, A.N. 1982. To spilaio tou Archanthropou ton petralonon: E anasa tis spilias. Vivliothiki anthropologikis etairias ellados, arithmos 3. Thessaloniki: Giannis Rekos ke Sia (in Greek)
- Poulos, S.E. 2009. Origin and distribution of the terrigenous component of the unconsolidated surface sediment of the Aegean floor: a synthesis. *Continental Shelf Research* 29, 2045-60
- Preece, R.C., Gowlett, J.A.J., Parfitt, S.A., Bridgeland, D. R. and Lewis, S.G. 2006. Humans in the Hoxnian: habitat, context and fire use at Breeches Pit, West Stow, Suffolk, UK. *Journal of Quaternary Science* 21 (5), 485-96
- Prentice, I.C., Guiot, J. and Harrison, S.P. 1992. Mediterranean vegetation, lake levels and palaeoclimate at the Last Glacial Maximum. *Nature* 360, 658-60
- Psilovikos, A. and Syrides, G. 1984. Neogene and Quaternary palaeoenvironments in the northern Aegean area. *Annales Géologiques des Pays Helléniques* 32, 105-14
- Pyle, D.M., van Andel, T.H., Paschos P. and van den Bogaard, P. 1998. An exceptionally thick Middle Pleistocene tephra layer from Epirus, Greece. *Quaternary International* 49, 280-86
- Raia, P., Piras, P. and Kotsakis, T. 2006. Detection of Plio-Quaternary large mammal communities of Italy. An integration of fossil faunas biochronology and similarity. *Quaternary Science Reviews* 25, 846-54
- Raposo, L. and Santonja, M. 1995. The earliest occupation of Europe: the Iberian peninsula. In W. Roebroeks and T. van Kolfschoten (eds), *The earliest occupation of Europe: Proceedings of the European Science Foundation Workshop at Tautavel (France), November 1993*, 7-25. Leiden: Leiden University Press
- Raynal, J.-P., Geraads, D., Magoga, L., Elhajraoui, A., Texier, J.P., Lefevre, D. and Sbihi-Alaoui, F.Z. 1993. La Grotte des Rhinocéros (Carrière Oulad Hamida 1, anciennement Thomas III, Casablanca), nouveau site acheuléen du Maroc atlantique. *Comptes rendus de l'Académie des Sciences Paris* (série II) 316, 1477-83
- Raynal, J.-P., Magoga, L., Sbihi-Alaoui, F.-Z. and Geraads, D. 1995. The earliest occupation of Atlantic Morocco: the Casablanca evidence. In W. Roebroeks and T. van Kolfschoten (eds), *The Earliest Occupation of Europe: Proceedings of the European Science Foundation Workshop at Tautavel (France), November 1993*, 255-62. Leiden: Leiden University Press
- Raynal, J.-P., Sbihi-Alaoui, F.Z., Geraads, D., Magoga, L. and Mohi, A. 2001. The earliest occupation of North-Africa: the Moroccan perspective. *Quaternary International* 75, 65-75
- Raynal, J.-P., Sbihi-Alaoui, F.Z., Magoga, L., Mohi, A. and Zouak, M. 2002. Casablanca and the earliest occupation of north Atlantic Morocco. *Quaternaire* 13 (1), 65-77
- Raynal, J.-P. and Texier, J.P. 1989. Découverte d'Acheuléen ancien dans la carrière Thomas I a Casablanca et problème de l'ancienneté de la présence humaine au Maroc. *Comptes rendus de l'Académie des Sciences Paris* (série II) 308, 1743-9
- Raynal, J.-P., Texier, J.P., Geraads, D. and Sbihi-Alaoui, F. Z. 1990. Un nouveau gisement paléontologique plio-pléistocène en Afrique du Nord : Ahl Al Oughlam

- (ancienne carrière Deprez) à Casablanca (Maroc) 1990. *Comptes rendus de l'Académie des Sciences Paris* (série II) 310, 315-20
- Reynard, E. and Coratza, P. 2007. Geomorphosites and geodiversity: a new domain of research. *Geographica Helvetica* 62, 138-9
- Raynaud, D., Barnola, J.-M., Souchez, R., Lorrain, R., Petit, J.-R., Duval, P. and Lipenkov, V.Y. 2005. The record for marine isotope stage 11. *Nature* 436, 39-40
- Reilinger, R., McClusky, S., Paradissis, D., Ergintav, S. and Vernant, P. 2010. Geodetic constraints on the tectonic evolution of the Aegean region and strain accumulation along the Hellenic subduction zone. *Tectonophysics* 488, 22-30
- Reisch, L. 1982. The transition from Lower to Middle Palaeolithic in Greece and the southern Balkan. In A. Ronen (ed.), *The transition from Lower to Middle Palaeolithic and the origins of modern man*, 223-31. Oxford: British Archaeological Report 151
- Rettalack, G.J. 2001. *Soils of the Past: An Introduction to Paleopedology*. London: Blackwell Science
- Rhodes, E.J., Raynal, J.-P., Geraads, D. and Sbihi-Alaoui, F.Z. 1994. Premières dates RPE pour l'Acheuléen du Maroc atlantique (Grotte des Rhinocéros, Casablanca). *Comptes rendus de l'Académie des Sciences Paris* (série II) 319, 1109-15
- Richards, M., Harvati, K., Grimes, V., Smith, C., Smith, T., Hublin, J.-J., Karkanas, P. and Panagopoulou, E. 2008. Strontium isotope evidence of Neanderthal mobility at the site of Lakonis, Greece using laser-ablation PIMMS. *Journal of Archaeological Science* 35, 1251-56
- Rick, J.W. 1976. Downslope movement and archaeological intrasite spatial analysis. *American Antiquity* 41 (2), 133-44
- Ríos, J., Iriarte, E., Garate, D., Cearreta, A. and Iriarte, M. J. 2008. The Mendieta site (Sopelana, Biscay province, northern Spain): palaeoenvironment and formation processes of a Lower Palaeolithic open-air archaeological deposit. *Comptes Rendus Palevol* 7, 453-62
- Robertson, A.H.F. and D. Mountrakis 2006. Tectonic development of the Eastern Mediterranean region: an introduction. In A.H.F. Robertson and Mountrakis, D. (eds), *Tectonic Development of the Eastern Mediterranean Region*, 1-9. London: Geological Society Special Publication 260
- Rodríguez-Sánchez, F., Pérez-Barrales, R., Ojeda, F., Vargas, P. and Arroyo, J. 2008. The strait of Gibraltar as a melting pot for plant biodiversity. *Quaternary Science Reviews* 27, 2100-17
- Roebroeks, W. 1994. Updating the earliest occupation of Europe. *Current Anthropology* 35, 301-4
- Roebroeks, W. 2001. Hominid behaviour and the earliest occupation of Europe: an exploration. *Journal of Human Evolution* 41, 437-61
- Roebroeks, W. 2006. The human colonization of Europe: where are we? *Journal of Quaternary Science* 21 (5), 425-35
- Roebroeks, W. and Corbey, R. 2001. Biases and double standards in palaeoanthropology. In R. Corbey and W. Roebroeks (eds), *Studying human origins: disciplinary history and epistemology*, 67-76. Amsterdam: Amsterdam University Press
- Roebroeks, W., Kolen, J. and E. Rensink 1988. Planning depth, anticipation and the organization of Middle Palaeolithic technology: the "archaic natives" meet Eve's descendants. *Helinium* XXVIII (1), 17-34
- Roebroeks, W. and Tuffreau, A. 1999. Palaeoenvironmental and settlement patterns of the Northwest European Middle Palaeolithic. In W. Roebroeks and C. Gamble (eds), *The Middle Palaeolithic occupation of Europe*, 121-38. Leiden: University of Leiden
- Roebroeks, W. and van Kolfschoten, T. 1994. The earliest occupation of Europe: a short chronology. *Antiquity* 68, 489-503
- Roebroeks, W. and van Kolfschoten, T. 1995. The earliest occupation of Europe: a reappraisal of artefactual and chronological evidence. In W. Roebroeks and T. van Kolfschoten (eds), *The earliest occupation of Europe: Proceedings of the European Science Foundation workshop at Tautavel (France), 1993*, 297-315. Leiden: University of Leiden
- Rogers, R.D. and Schumm, S.A. 1991. The effect of sparse vegetative cover on erosion and sediment yield. *Journal of Hydrology* 123, 19-24
- Rohais, S., Eschard, R., Ford, M., Guillocheau, F. and Moretti, I. 2007. Stratigraphic architecture of the Plio-Pleistocene infill of the Corinth Rift: implications for its structural evolution. *Tectonophysics* 440, 5-28
- Rohais, S., Eschard, R. and Guillocheau, F. 2008. Depositional model and stratigraphic architecture of rift climax Gilbert-type fan deltas (Gulf of Corinth, Greece). *Sedimentary Geology* 210, 132-45
- Rohling, E.J., Fenton, M., Jorissen, F.J., Bertrand, P., Ganssen, G. and Caulet, J.P. 1998. Magnitudes of sea-level lowstands of the past 500,000 years. *Nature* 394, 162-65
- Rolland, N. 2010. The earliest hominid dispersal beyond Sub-Saharan Africa: a survey of underlying causes. *Quaternary International* 223-224, 54-64
- Romero Díaz, M.A., Cabezas, E. and López Bermúdez, E. 1992. Erosion and fluvial sedimentation in the River Segura Basin (Spain). *Catena* 19, 379-92
- Ron, H. and Levi, S. 2001. When did hominins first leave Africa? New high-resolution magnetostratigraphy

- from the Erk-el-Ahmar Formation, Israel. *Geology* 29, 887-90
- Ron, H., Porat, N., Ronen, A., Tchernov, E. and Horwitz, L.K. 2003. Magnetostratigraphy of the Evron Member –implications for the age of the Middle Acheulian site of Evron Quarry. *Journal of Human Evolution* 44, 633-9
- Rondoyanni, Th., Georgiou, Ch., Galanakis, D. and Kourouzidis, M. 2004. Evidences of active faulting in Thrace region (North-Eastern Greece). Proceedings of the 10th International Congress, Thessaloniki, April 2004. *Bulletin of the Geological Society of Greece* XXXVI, 1671-78
- Ronen, A. 2003. The small tools of Evron-Quarry, western Galilee, Israel. In J.M. Burdukiewicz and A. Ronen (eds), *Lower Palaeolithic small tools in Europe and the Levant*, 113-20. Oxford: British Archaeological Reports 1115
- Ronen, A. 2006. The oldest human groups in the Levant. *Comptes Rendus Palevol* 5, 343-51
- Roucoux, K.H., Shackleton, N.J. and de Abreu, L. 2001. Combined marine proxy and pollen analyses reveal rapid vegetation response to North Atlantic millennial-scale climate oscillations. *Quaternary Research* 56, 128-32
- Roucoux, K.H., Tzedakis, P.C., de Abreu, L. and Shackleton, N.J. 2006. Climate and vegetation changes 180,000 to 345,000 years ago recorded in a deep-sea core off Portugal. *Earth and Planetary Science Letters* 249, 307-25
- Roucoux, K.H., Tzedakis, P.C., Frogley, M.R., Lawson, I. T and Preece, R.C. 2008. Vegetation history of the Marine Isotope Stage 7 interglacial complex at Ioannina, NW Greece. *Quaternary Science Reviews* 27, 1378-95
- Roussakis, G., Karageorgis, A.P., Conispoliatis, N. and Lykousis, V. 2004. Last glacial-Holocene sediment sequences in N. Aegean basins: structure, accumulation rates and clay mineral distribution. *Geo-Marine Letters* 24, 97-111
- Roussos, N. and Lyssimachou, T. 1991. Structure of the Central North Aegean Trough: an active strike-slip deformation zone. *Basin Research* 3, 39-48
- Rozos, D., Pyrgiotis, L., Skias, S. and Tsagaratos, P. 2008. An implementation of rock engineering system for ranking the instability potential of natural slopes in Greek territory: an application in Karditsa County. *Landslides* 5, 261-70
- Runnels, C. 1988. A prehistoric survey of Thessaly: new light on the Greek Middle Palaeolithic. *Journal of Field Archaeology* 15, 277-90
- Runnels, C. 1995. Review of Aegean Prehistory IV: The Stone Age of Greece from the Palaeolithic to the advent of Neolithic. *American Journal of Archaeology* 99, 699-728
- Runnels, C. 2003a. The history and future prospects of Palaeolithic archaeology in Greece. In J.K. Papadopoulos and R.M. Leventhal (eds), *Theory and practice in Mediterranean archaeology: Old World and New World perspectives*, 181-93. Los Angeles: Cotsen Institute of Archaeology
- Runnels, C. 2003b. The Lower Palaeolithic of Greece and NW Turkey. In M. Özbaşaran, O. Tanindi and A. Boratav (eds.), *Archaeological Essays in Honour of Homo amatus: Güven Arsebük*, 195-202. İstanbul: Ege Yayınları
- Runnels, C., Korkuti, M., Galary, M.L., Timpson, M.E., Stocker, S.R., Davis, J.L. and Muçaj, S. 2009. Early prehistoric landscape and land-use in the Fier region of Albania. *Journal of Mediterranean Archaeology* 22 (2), 151-82
- Runnels, C. and Özdoğan, M. 2001. The Palaeolithic of the Bosphorus Region, NW Turkey. *Journal of field Archaeology* 28, 69-92
- Runnels, C. and van Andel, T.H. 1993a. A handaxe from Kokkinopilos, Epirus, and its implications for the Palaeolithic of Greece. *Journal of Field Archaeology* 20, 191-203
- Runnels, C. and van Andel, T.H. 1993b. The Lower and Middle Palaeolithic of Thessaly, Greece. *Journal of Field Archaeology* 20: 299-317
- Runnels, C. and van Andel, T. 1999. The Palaeolithic in Larissa, Thessaly. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès & K. Zachos (eds), *The Palaeolithic Archaeology of Greece and Adjacent Areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 215-220. London: British School at Athens Studies 3
- Runnels, C. and van Andel, T.H. 2003. The Early Stone Age of the Nomos of Preveza: landscape and settlement. In J. Wiseman and K. Zachos (eds.), *Landscape Archaeology in Southern Epirus, Greece I*, Hesperia Supplement 32, 47-133. Athens: American School of Classical Studies at Athens
- Runnels, C., van Andel, T.H., Zachos, K. and Paschos, P. 1999. Human settlement and landscape in the Preveza region (Epirus) in the Pleistocene and early Holocene. In G.N. Bailey, E. Adam, E. Panagopoulou, C. Perlès and K. Zachos (eds), *The Palaeolithic archaeology of Greece and adjacent areas: Proceedings of the ICOPAG Conference, Ioannina, September 1994*, 120-29. Athens: British School at Athens Studies 3
- Sabatakakis, N., Koukis, G. and Mourtas, D. 2005. Composite landslides induced by heavy rainfalls in suburban areas: city of Patras and surrounding area, western Greece. *Landslides* 2, 202-11

- Sahnouni, M. 1998. *The Lower Palaeolithic of the Maghreb: Excavations and analyses at Ain Hanech, Algeria*. Cambridge Monographs in African Archaeology 42, Oxford: British Archaeological Reports International Series 689
- Sahnouni, M. and de Heinzelin, J. 1998. The site of Ain Hanech revisited: new investigations at this Lower Palaeolithic site in Northern Algeria. *Journal of Archaeological Science* 25, 1083-1101
- Sahnouni, M., Hadjouis, D., van der Made, J., Derradji, A., Canals, A., Medig, M. and Belahrech, H. 2002. Further research at the Oldowan site of Ain Hanech, north-eastern Algeria. *Journal of Human Evolution* 43, 925-37
- Sahnouni, M., Hadjouis, D., van der Made, J., Derradji, A., Canals, A., Medig, M., Belahrech, H., Harichane, Z. and Rabhi, M. 2004. On the human occupation in North Africa: a response to Geraads et al. *Journal of Human Evolution* 46, 763-75
- Sahnouni, M., van der Made, J. and Everett, M. in press. Ecological background to Plio-Pleistocene hominin occupation in North Africa: the vertebrate faunas from Ain Boucherit, Ain Hanech and El-Kherba, and paleosol stable-carbon-isotope studies from El-Kherba, Algeria. *Quaternary Science Reviews*
- Sakellariou, D., Lykousis, V., Alexandri, S., Kaberi, H., Rousakis, G., Nomikou, P., Georgiou, P. and Ballas, D. 2007. Faulting, seismic-stratigraphic architecture and late Quaternary evolution of the Gulf of Alyonides Basin-East Gulf of Corinth, Central Greece. *Basin Research* 19, 273-95
- Sala, B. 1991. A preliminary report on the microvertebrates of Notarchirico, Venosa. *Preistoria Alpina* 25, 7-14 (1989)
- Sala, B. and Masini, F. 2007. Late Pliocene and Pleistocene small mammal chronology in the Italian peninsula. *Quaternary International* 160, 4-16
- Sampson, A. 2006. *The prehistory of the Aegean basin: Palaeolithic, Mesolithic, Neolithic*. Athens: Atrapos
- Santisteban, J. I. and Schulte, L. 2007. Fluvial records of the Iberian Peninsula: a chronological framework. *Quaternary Science Reviews* 26, 2738-57
- Santonja, M. and Pérez-González, A. 2010. Mid-Pleistocene Acheulean industrial complex in the Iberian Peninsula. *Quaternary International* 223-224, 154-61
- Santonja, M. and Villa, P. 1990. The Lower Palaeolithic of Spain and Portugal. *Journal of World Prehistory* 4, 45-94
- Santonja, M. and Villa, P. 2006. The Acheulian of Western Europe. In N. Goren-Inbar and G. Sharon (eds), *Axe Age: Acheulian tool-making from quarry to discard*, 429-78. London: Equinox
- Saragusti, I. and Goren-Inbar, N. 2001. The biface assemblage from Gesher Benot Ya'akov, Israel: illuminating patterns in "Out of Africa" dispersal. *Quaternary International* 75, 85-9
- Sarantea-Micha, E. 1996. Phaneromeni and Voleri, Nea Artaki in Euboea: palaeolithic quarries and tool workshops. *Archaiologia kai Technes* 60, 43-7 (in Greek)
- Sardella, R., Palombo, M.R., Petronio, C., Bedetti, C. and Pavia, M. 2006. The early Middle Pleistocene large mammal faunas of Italy: an overview. *Quaternary International* 149, 104-9
- Schaller, M., von Blanckenburg, F., Hovius, N. and Kubik, P.W. 2001. Large-scale erosion rates from in situ-produced cosmogenic nuclides in European river sediments. *Earth and Planetary Science Letters* 188, 441-58
- Schattner, U. 2010. What triggered the early-to-mid Pleistocene tectonic transition across the entire eastern Mediterranean? *Earth and Planetary Science Letters* 289, 539-548
- Schattner, U. and Lazar, M. 2009. Subduction, collision and initiation of hominin dispersal. *Quaternary Science Reviews* 28, 1820-4
- Schick, K.D. 1987. Experimentally-derived criteria for assessing hydrologic disturbance of archaeological sites. In D.T. Nash and M.D. Petraglia (eds), *Natural Formation Processes and the Archaeological Record*, 86-107. Oxford: British Archaeological Reports International Series 352
- Schiffer, M.B. 1987. *Formation processes of the archaeological record*. Albuquerque: University of New Mexico Press
- Schneider, H.E. 1968. *Zur Quartärgeologischen Entwicklungsgeschichte Thessaliens (Griechenland)*. Bonn: Rudolf Habelt Verlag
- Schumm, S.A. 1963. The disparity between present rates of denudation and orogeny. *United States Geological Survey Professional Papers* 454, 14
- Schumm, S.A. 1979. Geomorphic thresholds: the concept and its applications. *Transactions of the Institute of the British Geographers (New Series)* 4 (4), 485-515
- Scott, G.R. and Gibert, L.I. 2009. The oldest hand-axes in Europe. *Nature* 461, 82-5
- Scott, G.R., Gibert, L. and Gibert, J. 2007. Magnetostratigraphy of the Orce region (Baza Basin), SE Spain: new chronologies for Early Pleistocene faunas and hominid occupation sites. *Quaternary Science Reviews* 26, 415-35
- Segre, A. and Ascenzi, A. 1984. Fontana Ranuccio: Italy's earliest Middle Pleistocene hominid site. *Current Anthropology* 25 (2), 230-3

- Semaw, S., Rogers, M.J., Ouade, J., Renne, P.R., Butler, R.F., Dominguez-Rodrigo, M., Stout, D., Hart, W.S., Pickering, T. and Simpson, S.W. 2003. 2.6-Million-year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *Journal of Human Evolution* 45, 169-77
- Sengör, A.M.C., Tüysüz, O., Imren, C., Sakinc, M., Eyidogan, H., Görür, N., Le Pichon, X. and Rangin, C. 2005. The North Anatolian Fault: a new look. *Annual Reviews in Earth and Planetary Sciences* 33, 37-112
- Servais, J. 1961. Outils paléolithiques d'Élide. *Bulletin de la Correspondance Hellénique* 85, 1-9
- Shackleton, N.J. 1987. Oxygen isotopes, ice volume and sea level. *Quaternary Science Reviews* 6, 183-90
- Shackleton, N.J., M.F. Sanchez-Goni, D. Paillet and Y. Lancelot 2003. Marine Isotope Stage 5e and the Eemian Interglacial. *Global and Planetary Change* 36, 151-5
- Sharp, W.D., Ludwig, K.R., Chadwick, O.A., Amundson, R. and Glaser, L.L. 2003. Dating fluvial terraces by $^{230}\text{Th}/\text{U}$ on pedogenic carbonate, Wind River Basin, Wyoming. *Quaternary Research* 59, 139-50
- Siavalas, G., Linou, M., Chatziapostolou, A., Kalaitzidis, S., Papaefthymiou, H. and Christianis, K. 2009. Palaeoenvironment of Seam I in the Marathousa Lignite Mine, Megalopolis Basin (Southern Greece). *International Journal of Coal Geology* 78, 233-48
- Sickenberg, O. 1975. Eine Säugertierfauna des tieferen Bihariums aus dem Becken von Megalopolis (Peloponnes, Griechenland). *Annales Géologiques des Pays Helléniques* 27, 25-73
- Siddall, M., Rohling, E.J., Almogi-Labin, A., Hemleben, Ch., Meischner, D., Schmelzer, I. and Smeed, D.A. 2003. Sea-level fluctuations during the last glacial cycle. *Nature* 423, 853-58
- Sidorchuk, A. 2009. A third generation erosion model: the combination of probabilistic and deterministic components. *Geomorphology* 110, 2-10
- Simms, M.J. 1994. Emplacement and preservation of vertebrates in caves and fissures. *Zoological journal of the Linnean Society* 112, 261-83
- Sirakov, N., Guadelli, J.-L., Ivanova, S., Sirakova, S., Boudadi-Maligne, M., Dimitrova, I., Fernandez, Ph., Ferrier, C., Guadelli, A., Iordanova, D., Kovatcheva, M., Krumov, I., Leblanc, J.-Cl., Miteva, V., Popov, V., Spassov, R., Taneva, S. and Tsanova, T. 2010. An ancient continuous human presence in the Balkans and the beginnings of human settlement in western Eurasia: A Lower Pleistocene example of the Lower Palaeolithic levels in Kozarnika cave (North-western Bulgaria). *Quaternary International* 223-224, 94-106
- Sitlivy, V., Sobczyk, K., Karkanis, P. and Koumouzelis M. 2007. Middle Palaeolithic lithic assemblages of the Klisoura cave, Peloponnesus, Greece: a comparative analysis. *Archaeology, Ethnology and Anthropology of Eurasia* 3, 2-15
- Skuphos, T.G. 1905. Über die palaeontologischen Ausgrabungen in Griechenland in Beziehung auf das Vorhandensein des Menschen. *Comptes Rendus du Congrès International d'Archéologie*, 231-36. Athènes
- Slimak, L., Kuhn, S., Roche, H., Mouralis, D., Buitenhuis, H., Balkan-Ath, N., Binder, D., Kuzuzuoglu, C. and Guillou, H. 2008. Kaletepe Deresi 3 (Turkey): archaeological evidence for early human settlement in Central Anatolia. *Journal of Human Evolution* 54, 99-111
- Smith, G.W., R.D. Nance and A.N. Genes 1997. Quaternary glacial history of Mount Olympus. *Geological Society of America Bulletin* 109, 809-24
- Snel, E., Mărunțeanu, M. and Meulenkamp, J.E. 2006. Calcareous nannofossil biostratigraphy and magnetostratigraphy of the Upper Miocene and Lower Pliocene of the Northern Aegean (Orphanic Gulf-Strimon Basin areas), Greece. *Palaeogeography, Palaeoclimatology, Palaeoecology* 238, 125-50
- Sommer, R.S. and Nadachowski, A. 2006. Glacial refugia of mammals in Europe: evidence from fossil records. *Mammal Review* 36 (4), 251-65
- Sordinas, A. 1969. Investigations of the prehistory of Corfu during 1964-1965. *Balkan Studies* 10, 393-424
- Sordinas, A. 1970. Lithic tools from prehistoric Zakynthos. *Kerkyraika Chronika* 15, 122-30 (in Greek)
- Spassov, N. 2002. The Late Villafranchian and biochronology of South-East Europe: faunal migrations, environmental changes and possible first appearance of the genus *Homo* on the continent. *Annales Géologiques des Pays Helléniques* 39A, 221-43
- Stallard, R.E. 1995. Tectonic, environmental, and human aspects of weathering and erosion: a global review using a steady-state perspective. *Annual Review of Earth and Planetary Sciences* 23, 11-39
- Stanley, D.J. and Perissoratis, C. 1977. Aegean Sea ridge barrier-and-basin sedimentation patterns. *Marine Geology* 24, 97-107
- Starkel, L. 2003. Climatically controlled terraces in uplifting mountain areas. *Quaternary Science Reviews* 22, 2189-98
- Stearns, C.E. 1978. Pliocene-Pleistocene emergence of the Moroccan Meseta. *Geological Society of the American Bulletin* 89, 1630-44
- Stiros, S.C. 2009. Earthquakes. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 469-91. Oxford: Oxford University Press

- Storme, A.L.H. 2008. *The landscape at Zakynthos: detailed geomorphological description of the south-eastern part of the Vassilikos Peninsula*. Unpublished MSc Thesis, Amsterdam: Vrije Universiteit
- Strasser, T.F., Panagopoulou, E., Runnels, C., Murray, P., Thompson, N., Karkanis, P., McCoy, F. and Wegmann, W. 2010. Stone Age seafaring in the Mediterranean: evidence from the Plakias region for Lower Palaeolithic and Mesolithic habitation of Crete. *Hesperia* 79 (2), 145-90
- Straus, L.G. 2001. Africa and Iberia in the Pleistocene. *Quaternary International* 75, 91-102
- Stringer, C.B. 1983. Some further notes on the morphology and dating of the Petralona hominid. *Journal of Human Evolution* 1983, 731-42
- Stringer, C.B. 1992. Evolution of early humans. In S. Jones, R. Martin and D. Pilbeam (eds.), *The Cambridge Encyclopedia of Human Evolution*, 241-51. Cambridge: Cambridge University Press
- Stringer, C.B. 2000a. Petralona. In A.S. Delson, I. Tattersall, J.A. van Couvering and A.S. Brooks (eds.), *Encyclopedia of Human Evolution and Prehistory*, 1144. New York: Garland Publishing, 2nd edition
- Stringer, C.B. 2000b. Coasting out of Africa. *Nature* 405, 53-5
- Stringer, C.B., Finlayson, J.C., Barton, R.N.E., Fernández-Jalvo, Y., Cáceres, I., Sabin, R.C., Rhodes, E.J., Currant, A.P., Rodríguez-Vidal, J., Giles-Pacheco, F. and Riquelme-Cantal, J.A. 2008. Neanderthal exploitation of marine mammals in Gibraltar. *Proceedings of the National Academy of Sciences of the United States of America* 105, 14319-324
- Stringer, C.B., F.C. Howell and J.K. Melentis 1979. The significance of the fossil hominid skull from Petralona, Greece. *Journal of Archaeological Science* 6, 235-53
- Stroosnijder, L. 2005. Measurement of erosion: is it possible? *Catena* 64, 162-73
- Stuart, A.J. 2005. The extinction of woolly mammoth (*Mammuthus primigenius*) and straight-tusked elephant (*Palaeoloxodon antiquus*) in Europe. *Quaternary International* 126-128, 171-7
- Sturdy, D., Webley, D. and Bailey, G. 1997. The Palaeolithic geography of Epirus. In G.N. Bailey (ed.), *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece, vol. 2: Klithi in its local and regional setting*, 587-614. Cambridge: McDonald Institute for Archaeological Research
- Suc, J.-P. 1984. Origin and evolution of the Mediterranean vegetation and climate in Europe. *Nature* 307, 429-32
- Suc, J.-P. and Popescu, S.-M. 2005. Pollen records and climatic cycles in the North Mediterranean region since 2.7 Ma. In M.J. Head and P.L. Gibbard (eds), *Early-Middle Pleistocene Transitions: the Land-Ocean Evidence*, 147-58. London: Geological Society Special Publications 247
- Surovell, T.A. and Brantingham, P.J. 2007. A note on the use of temporal frequency distributions in studies of prehistoric demography. *Journal of Archaeological Science* 34, 1868-77
- Surovell, T.A., Finley, J.B., Smith, G.M., Brantingham, P. J. and Kelly, R. 2009. Correcting temporal frequency distributions for taphonomic bias. *Journal of Archaeological Science* 36, 1715-24
- Szabó, K., Brumm, A. and Bellwood, P. 2007. Shell artefact production at 32,000-28,000 BP in island southeast Asia. *Current Anthropology* 48 (5), 701-23
- Taşkıran, H. 2008. Réflexions sur l' Acheuléen d'Anatolie. *L'anthropologie* 112, 140-52
- Tattersall, I. and Schwartz, J.H. 2009. Evolution of the Genus *Homo*. *Annual Review of Earth and Planetary Sciences* 37, 67-92
- Templeton, A.R. 2002. Out of Africa again and again. *Nature* 416, 45-51
- Texier, J.P., Lefevre, D. and Raynal, J.-P. 1994. Contribution pour un nouveau cadre stratigraphique des formations littorales quaternaires de la région de Casablanca. *Comptes rendus de l'Académie des Sciences Paris (série II)* 318 (9), 1247-53
- Texier, J.P., Raynal, J.-P. and Lefevre, D. 1985. Nouvelles propositions pour un cadre chronologique raisonne du Quaternaire marocain. *Comptes rendus de l'Académie des Sciences Paris (série II)* 301 (3), 183-8
- Theocharis, D. 1967. *The dawn of Thessalian prehistory*. Volos: Filarchaios Etaireia Volou (in Greek).
- Thieme, H. 1997. Lower Palaeolithic hunting spears from Germany. *Nature* 385, 807-10
- Thornes, J.B. 1985. The ecology of erosion. *Geography* 70 (3), 222-35
- Thornes, J.B. 2002. The evolving context of Mediterranean desertification. In N.A. Geeson, C.J. Brandt and J.B. Thornes (eds) *Mediterranean Desertification. A mosaic of Processes and Responses*, 5-11. Chichester: John Wiley & Sons
- Thornes, J.B. 2009. Land degradation. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 563-81. Oxford: Oxford University Press
- Thornes, J.B., López-Bermúdez, F. and Woodward, J.C. 2009. Hydrology, river regimes and sediment yield. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 229-53. Oxford: Oxford University Press
- Tourloukis, E. 2009. New bifaces from the Palaeolithic site of Kokkinopilos, Greece and their stratigraphic significance. *Antiquity* 83 (320) Project Gallery

- (available at <http://www.antiquity.ac.uk/projgall/tourloukis320/>)
- Tourloukis, E. and Palli, O. The first Medolithic site of Thesprotia. In B. Forsén (ed.), *Thesprotia Expedition I: towards a regional history*, 25-38. Helsinki: Papers and Monographs of the Finnish Institute at Athens XV
- Trauth, M.H., Larrasoña, J.C. and Mudelsee, M. 2009. Trends, rhythms and events in Plio-Pleistocene African climate. *Quaternary Science Reviews* 28, 399-411
- Tsapanos, T.M., Mäntyniemi, P. and Kijko, A. 2004. A probabilistic seismic hazard assessment for Greece and the surrounding region including site-specific considerations. *Annals of Geophysics* 47 (6), 1675-88
- Tselepidakis, I.G. and Theoharatos, G.A. 1989. A bioclimatic classification of the Greek area. *Theoretical and Applied Climatology* 40, 147-53
- Tsoukala, E.S. 1991. Contribution to the study of the Pleistocene fauna of large mammals (Carnivora, Perissodactyla, Artiodactyla) from Petralona Cave (Chalkidiki, N. Greece): Preliminary report. *Comptes rendus de l'Académie des Sciences Paris* 312 (série II), 331-36
- Tsoukala, E. 1999. Quaternary large mammals from the Apidima Caves (Lakonia, S Peloponnese, Greece). *Beiträge zur Paläontologie* 24, 207-29
- Tsoukala, E.S. and Melentis, J.K. 1994. *Deinotherium giganteum* KAUP (Proboscidea) from Kassandra Peninsula (Chalkidiki, Macedonia, Greece). *Geobios* 27 (5), 633-40
- Turner, C. 2002. Problems of the duration of the Eemian Interglacial in Europe north of the Alps. *Quaternary Research* 58, 45-8
- Tzedakis, P.C. 1994. Vegetation change through glacial-interglacial cycles: a long pollen sequence perspective. *Philosophical Transactions of the Royal Society of London B* 345, 403-32
- Tzedakis, P.C. 2000. Vegetation variability in Greece during the last interglacial. *Geologie en Mijnbouw / Netherlands Journal of Geosciences* 79, 255-367
- Tzedakis, P.C. 2005. Towards an understanding of the response of southern European vegetation to orbital and suborbital climate variability. *Quaternary Science Reviews* 24, 1585-99
- Tzedakis, P.C. 2007. Seven ambiguities in the Mediterranean palaeoenvironmental narrative. *Quaternary Science Reviews* 26, 2042-66
- Tzedakis, P.C., Andrieu, V., de Beaulieu, J.-L., Birks, H.J.B., Crowhurst, S., Follieri, M., Hooghiemstra, H., Magri, D., Reille, M., Sadori, L., Shackleton, N.J. and Wijmstra, T.A. 2001. Establishing a terrestrial chronological framework as a basis for biostratigraphical comparisons. *Quaternary Science Reviews* 20, 1583-92
- Tzedakis, P.C., Andrieu, V., de Beaulieu, J.-L., Crowhurst, S., Follieri, M., Hooghiemstra, H., Magri, D., Reille, M., Sadori, L., Shackleton, N.J. and Wijmstra, T.A. 1997. Comparison of terrestrial and marine records of changing climate of the last 500,000 years. *Earth and Planetary Science Letters* 150, 171-6
- Tzedakis, P.C., Frogley, M.R. and Heaton, T.H.E. 2002a. Duration of Last Interglacial Conditions in North-western Greece. *Quaternary Research* 58, 53-5
- Tzedakis, P.C., Frogley, M.R. and Heaton, T.H.E. 2003a. Last interglacial conditions in southern Europe: evidence from Ioannina, northwest Greece. *Global and Planetary Change* 36, 157-70
- Tzedakis, P.C., Frogley, M.R., Lawson, I.T., Preece, R.C., Cacho, I. and de Abreu, L. 2004a. Ecological thresholds and patterns of millennial-scale climate variability: The response of vegetation in Greece during the last glacial period. *Geological Society of America* 32 (2), 109-12
- Tzedakis, P.C., Hooghiemstra, H. and Pälike, H. 2006. The last 1.35 million years at Tenaghi Philippon: revised chronostratigraphy and long-term vegetation trends. *Quaternary Science Reviews* 25 (23-24), 3416-30
- Tzedakis, P.C., Lawson, I.T., Frogley, M.R., Hewitt, G.M. and Preece, R.C. 2002b. Buffered tree population changes in a Quaternary refugium: evolutionary implications. *Science* 297, 2044-7
- Tzedakis, P.C., McManus, J.F., Hooghiemstra, H., Oppo, D.W. and Wijmstra, T.A. 2003b. Comparison of changes in vegetation in northeast Greece with records of climate variability on orbital and suborbital frequencies over the last 450 000 years. *Earth and Planetary Science Letters* 212, 197-212
- Tzedakis, P.C., Roucoux, K.H., de Abreu, L. and Shackleton, N.J. 2004b. The duration of forest stages in Southern Europe and interglacial climate variability. *Science* 306, 2231-5
- Uluğ, A., Duman, M., Ersoy, S., Özel, E. and Avci, M. 2005. Late Quaternary sea-level change, sedimentation and neotectonics of the Gulf of Gökova: south-eastern Aegean Sea. *Marine Geology* 221, 381-95
- UNESCO-FAO 1963. Bioclimatic map of the Mediterranean zone. *Ecological Study of the Mediterranean Zone, Arid Zone Research*. Paris: UNESCO
- Valladas, H., Mercier, N., Froget, L., Joron, J.-L., Reyss, J.-L., Karkanas, P., Panagopoulou, E. and Kyparissi-Apostolika, N. 2007. TL age estimates for the Middle Palaeolithic layers at Theopetra cave (Greece). *Quaternary Geochronology* 2, 303-8

- Van Andel, T.H. 1989. Late Quaternary sea-level changes and archaeology. *Antiquity* 63, 733-45
- Van Andel, T.H. 1998. Paleosols, red sediments and the Old Stone Age in Greece. *Geoarchaeology* 13, 361-90
- Van Andel, T.H. and Lianos, N. 1984. High-resolution seismic reflection profiles for the reconstruction of postglacial transgressive shorelines: an example from Greece. *Quaternary Research* 22, 31-45
- Van Andel, T.H. and Perissoratis, C. 2006. Late Quaternary depositional history of the North Evvoikos Gulf, Aegean Sea, Greece. *Marine Geology* 232, 157-72
- Van Andel, T.H. and Runnels, C. 2005. Karstic wetland dwellers of Middle Palaeolithic Epirus, Greece. *Journal of Field Archaeology* 30 (4), 367-84
- Van Andel, T.H., Runnels, C. and Pope, K.O. 1986. Five thousand years of land use and abuse in the Southern Argolid, Greece. *Hesperia* 55, 103-28
- Van Andel, T.H. and Shackleton, J.C. 1982. Late Palaeolithic and Mesolithic coastlines of Greece and the Aegean. *Journal of Field Archaeology* 9 (4), 445-54
- Van Andel, T.H. and Tzedakis, P.C. 1996. Palaeolithic landscapes of Europe and environs, 150,000-25,000 years ago: an overview. *Quaternary Science Reviews* 15, 481-500
- Van Andel, T.H. and Zangger, E. 1990. Landscape stability and destabilization in the prehistory of Greece. In S. Bottema, G. Emtjes-Nieborg and W. van Zeist (eds.), *Man's role in the shaping of the eastern Mediterranean landscape*, 139-57. Rotterdam: Balkema
- Van Andel, T.H., Zangger, E. and Demitrack, A. 1990a. Land use and soil erosion in prehistoric and historical Greece. *Journal of Field Archaeology* 17, 379-96
- Van Andel, T.H., Zangger, E. and Perissoratis, C. 1990b. Quaternary transgressive / regressive cycles in the Gulf of Argos, Greece. *Quaternary Research* 34, 317-29
- Van der Made, J. and Mateos, A. 2010. Longstanding biogeographic patterns and the dispersal of early *Homo* out of Africa and into Europe. *Quaternary International* 223-224, 195-200
- Van der Meulen, A.J. and van Kolfschoten, T. 1986. Review of the Late Turolian to Early Biharian mammal faunas from Greece and Turkey. *Memorie della Società Geologica Italiana* 31, 201-11
- Van Hinsbergen, D.J.J. 2004. *The evolving anatomy of a collapsing orogen*. Ph.D. Thesis, Geologica Ultraiectina 243. Utrecht: Utrecht University
- Van Hinsbergen D.J.J., Lengereis, C.G. and Meulencamp, J.E. 2005. Revision of the timing, magnitude and distribution of Neogene rotations in the western Aegean region. *Tectonophysics* 396, 1-34
- Van Hinsbergen, D.J.J., van der Meer, D.G., Zachariasse, W.J. and Meulencamp, J.E. 2006. Deformation of western Greece during Neogene clockwise rotation and collision with Apulia. *International Journal of Earth Sciences* (Geologische Rundschau) 95, 463-90
- Van Kolfschoten, T. 1998. Biostratigraphical evidence of the earliest occupation of Europe. In E. Carbonell, J. M. Bermúdez de Castro, J.L. Arsuaga and X.P. Rodríguez (eds), *Los primeros pobladores de Europa: Últimos descubrimientos y debate actual*, 101-15. Burgos: Diario de Burgos
- Van Kolfschoten, T. 2007. Quaternary Stratigraphy/Biostratigraphy. In S.A. Elias (ed), *Encyclopedia of Quaternary Science*, 2808-11. Amsterdam: Elsevier
- Van Vugt, N., de Bruijn, H., van Kolfschoten, T. and Langereis, C.G. 2000. Magneto- and cyclostratigraphy and mammal-fauna's of the Pleistocene lacustrine Megalopolis Basin, Peloponnesos, Greece. *Geological Ultraiectina* 189, 69-92
- Van Wijngaarden, G.J.M., Arapogianni, X., Tourloukis, V. and Rink, R. 2006. The Zakynthos Survey 2005: preliminary report of a pilot survey. *Pharos* 13, 59-76 (2005)
- Van Wijngaarden, G.J.M., Sotiriou, A., Horn Lopes, J., Gkouma, M., Koster, K., Stoker, A., Susan, D. and Tourloukis, V. 2009. The Zakynthos Archaeology Project: preliminary report on the 2008 season. *Pharos* XVI, 61-83 (2008)
- Van Wijngaarden, G.J.M., Sotiriou, A., Pieters, A. and Tourloukis, V. 2007. The Zakynthos Archaeology Project 2006: preliminary report of the first season. *Pharos* 14, 29-46 (2006)
- Vandekerckhove, L., Poesen, J., Oostwoud Wijdenes, D. and de Figueiredo, T. 1998. Topographical thresholds for ephemeral gully initiation in intensively cultivated areas of the Mediterranean. *Catena* 33, 271-92
- Vandekerckhove, L., Poesen, J., Oostwoud Wijdenes, D., Nachtergaele, J., Kosmas, C., Roxo, M.J. and de Figueiredo, T. 2000. Thresholds for gully initiation and sedimentation in Mediterranean Europe. *Earth Surface Processes and Landforms* 25, 1201-20
- Vandenberghe, J. 1995. Timescales, climate and river development. *Quaternary Science Reviews* 14, 631-8
- Vandenberghe, J. 2003. Climate forcing of fluvial system development: an evolution of ideas. *Quaternary Science Reviews* 22, 2053-60
- Vandenberghe, J. 2008. The fluvial cycle at cold-warm-cold transitions in lowland regions: a refinement of theory. *Geomorphology* 98, 275-84
- Verheijen, F.G.A., Jones, R.J.A., Rickson, R.J. and Smith, C.J. 2009. Tolerable versus actual soil erosion rates in Europe. *Earth-Science Reviews* 94, 23-38

- Villa, P. 1996. The first Italians: Le industrie litiche del giacimento paleolitico di Isernia La Pineta. *Lithic Technology* 21 (1), 71-9
- Villa, P. 2001. Early Italy and the colonization of Western Europe. *Quaternary International* 75, 113-30
- Villa, P., Soto, E., Santonja, M., Pérez-González, A., Mora, R., Parcerisas, J. and Sesé, C. 2005. New data from Ambrona: closing the hunting versus scavenging debate. *Quaternary International* 126-8, 223-50
- Vinken, R. 1965. Stratigraphie und Tektonik des Beckens von Megalopolis (Peloponnes, Griechenland). *Geologisches Jahrbuch* 83, 97-148
- Vita-Finzi, C. 1969. *The Mediterranean valleys*. Cambridge: Cambridge University Press
- Von Blanckenburg, F. 2005. The control mechanisms of erosion and weathering at basin scale from cosmogenic nuclides in river sediment. *Earth and Planetary Science Letters* 237, 462-79
- Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J.C., McManus, J.F., Lambeck, K., Balbon, E. and Labracherie, M. 2002. Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records. *Quaternary Science Reviews* 21, 295-305
- Wainwright, J. 1992. Assessing the impact of erosion on semi-arid archaeological sites. In J. Boardman and M. Bell (eds), *Past and Present Soil Erosion*, 227-41. Oxford: Oxbow Books
- Wainwright, J. 2009. Weathering, soils and slope processes. In J.C. Woodward (ed.), *The Physical Geography of the Mediterranean*, 169-202. Oxford: Oxford University Press
- Ward, I. and Larcombe, P. 2003. A process-oriented approach to archaeological site formation: application to semi-arid Northern Australia. *Journal of Archaeological Science* 30, 1223-36
- Waters, M.R. and Kuehn, D.D. 1996. The Geoarchaeology of place: the effect of geological processes on the preservation and interpretation of the archaeological record. *American Antiquity* 61, 483-97
- Wells, L.E. 2001. A geomorphological approach to reconstructing archaeological settlement patterns based on surficial artifact distribution: replacing humans on the landscape. In P. Goldberg, V.T. Holliday and C.R. Ferring (eds), *Earth Sciences and Archaeology*, 107-41. New York: Kluwer Academic / Plenum Publishers
- Westaway, R. 2002. Long-term river terrace sequences: Evidence for global increases in surface uplift rates in the Late Pliocene and early Middle Pleistocene caused by flow in the lower continental crust induced by surface processes. *Netherlands Journal of Geosciences* 81, 305-28
- Westaway, R. 2007. Improved modeling of the Quaternary evolution of the Gulf of Corinth, incorporating erosion and sedimentation coupled by lower-crustal flow. *Tectonophysics* 440, 67-84
- Westley, K. and Dix, J. 2006. Coastal environments and their role in prehistoric migrations. *Journal of Maritime Archaeology* 1, 9-28
- Werz, B.E.J.S. and Flemming, N.C. 2001. Discovery in Table Bay of the oldest handaxes yet found underwater demonstrates preservation of hominid artefacts on the continental shelf. *South African Journal of Science* 97, 183-85
- White, M. and Ashton, N. 2003. Lower Palaeolithic core technology and the origins of the Levallois method in North-Western Europe. *Current Anthropology* 44 (4), 598-609
- Wilkinson, K.N. and Pope, R.J.J. 2003. Quaternary alluviation and archaeology in the Evrotas Valley, southern Greece. In A.J. Howard, M.G. Macklin and D.G. Passmore (eds), *Alluvial Archaeology in Europe*, 187-99. Lisse: Swets and Zeitlinger
- Willis, K.J. 1994. The vegetational history of the Balkans. *Quaternary Science Reviews* 13, 769-88
- Wintle, A.G. and Jacobs, J.A. 1982. A critical review of the dating evidence for Petralona cave. *Journal of Archaeological Science* 9, 39-47
- Wolpoff, M. 1980. Cranial remains of Middle Pleistocene European hominids. *Journal of Human Evolution* 9, 339-58
- Wood, B. and Collard, M. 1999. The Human Genus. *Science* 284, 65-71
- Woodward, J.C., Hamlin, R.H.B., Macklin, M.G., Hughes, P.D. and Lewin, J. 2008. Glacial activity and catchment dynamics in northwest Greece: long-term river behavior and the slackwater sediment record for the last glacial to interglacial transition. *Geomorphology* 101, 44-67
- Woodward, J.C., Lewin, J. and Macklin, M.G. 1995. Glaciation, river behavior and the Palaeolithic settlement of upland northwest Greece. In J. Lewin, M.G. Macklin and J.C. Woodward (eds), *Mediterranean Quaternary River Environments*, 115-29. Rotterdam: Balkema
- Woodward, J.C., Macklin, M.G. and Lewin, J. 1994. Pedogenic weathering and relative-age dating of Quaternary alluvial sediments in the Pindus Mountains of northwest Greece. In: D.A. Robinson and R. B.G. Williams (eds), *Rock weathering and landform evolution*, 259-83. Chichester: John Wiley & Sons
- Wrangham, R. 2009. *Catching fire: how cooking made us human*. New York: Basic Books

- Xeidakis, G.S., Delimani, P. and Skias, S. 2007. Erosion problems in Alexandroupolis coastline, north-eastern Greece. *Environmental Geology* 53, 835-48
- Xirotiris, N., Henke, W. and Symeonidis, N. 1979. Der M³ von Megalopolis –ein Beitrag zu seiner morphologischen Kennzeichnung. *Zeitschrift für Morphologie und Anthropologie* 70, 117-22
- Xoplaki, E., Gonzalez-Rouco, J.F., Gyalistras, D., Luterbacher, J., Rickli, R. and Wanner, H. 2003. Inter-annual summer air temperature variability over Greece and its connection to the large-scale atmospheric circulation and Mediterranean SSTs 1950-1999. *Climate Dynamics* 20, 537-54
- Yassoglou, N., Kosmas, C. and Moustakas, N. 1997. The red soils, their origins, properties, use and management in Greece. *Catena* 28, 261-78
- Yaalon, D.H. 1997. Soils in the Mediterranean region: what makes them different? *Catena* 28, 157-69
- Yaalon, D.H. 2009. Brief comments on red Mediterranean soils. *Catena* 76, 224
- Yokoo, Y., Sivapalan, M. and Oki, T. 2008. Investigating the roles of climate seasonality and landscape characteristics on mean annual and monthly water balances. *Journal of Hydrology* 357, 255-69
- Zangger, E. 1992. Neolithic to present soil erosion in Greece. In J. Boardman and M. Bell (eds), *Past and Present Soil Erosion*, 133-47. Oxford: Oxbow Books
- Zangger, E. 1994. Landscape changes around Tiryns during the Bronze Age. *American Journal of Archaeology* 98 (2), 189-212
- Zelilidis, A. and Kontopoulos, N. 1999. Plio-Pleistocene alluvial architecture in marginal extensional narrow sub-basins: examples from southwest Greece. *Geological Magazine* 136 (3), 241-62
- Zelilidis, A., Kontopoulos, N., Avramidis, P. and Piper, J. W.D. 1998. Tectonic and sedimentological evolution of the Pliocene-Quaternary basins of Zakynthos Island, Greece: case study of the transition from compressional to extensional tectonics. *Basin Research* 10, 393-408
- Zhou, L.P., van Andel, T.H. and Lang, A. 2000. A luminescence dating study of open-air Palaeolithic sites in western Epirus, Greece. *Journal of Archaeological Science* 27, 609-20
- Zwolinski, Z. 2004. Geodiversity. In A.S. Goudie (ed.), *Encyclopedia of Geomorphology*, 417-8. London: Routledge

English Summary

In the debate about early dispersals of hominins and the first occupation of Europe, the Mediterranean Basin holds a central position, as it seems to have been occupied significantly earlier than areas of the northern latitudes. Together with other parts of south-eastern Mediterranean and the Balkans, Greece is inferred to have been among the core areas for the peopling of major parts of Eurasia, serving as a ‘refugium’ and source region for populations in regions where occupation was intermittent due to climatic deteriorations. Therefore, the consensus in the palaeoanthropological community is that Greece would have been inhabited during the Lower Palaeolithic, particularly considering that early humans were present in adjacent regions with similar landscapes (Italy, Turkey and Bulgaria). Yet, in marked contrast to the rich evidence from excavated sites of the circum-Mediterranean region, Lower Palaeolithic material in Greece is scarce; it mostly consists of surface finds that have been ‘dated’ on the basis of their inferred archaic morphology and/or usually inadequate stratigraphic correlations.

Structured along a geoarchaeological axis, this study explores the reasons behind this apparent ‘absence of evidence’ from Greece. As the ultimate goal is to contribute to our knowledge of the Pleistocene occupation history of Greece and of the Mediterranean area in general, the investigation follows a three-stepped approach: the first stage seeks to *identify* the current status of the record, the second stage sets forth to *explain* this status, while the final step aspires to *put in prospect* the future of Lower Palaeolithic research in Greece.

In evaluating the Greek evidence, a framework of reference is needed and this is provided in chapters two and three. Chapter two overviews the main aspects of the Lower Palaeolithic period and outlines the critical issues related to early human dispersals and the po-

tential role of Greece in this subject. Chapter three reviews the evidence from the best-studied sites of the circum-Mediterranean region, focusing on the geomorphological environments of the sites, the typo-technological ascription of the lithic material and the available dating assays. In turn, this appraisal sets the background against which the Greek data is later juxtaposed.

Chapter four offers a critical assessment of all sites, findspots and isolated artefacts from Greece, which have been attributed to the Lower Palaeolithic period. Here the emphasis is on the artefactual material, its depositional setting, any associated dating and the argumentation for an ascription to the Lower Palaeolithic. Special attention is given to the evidence from the provinces of Epirus and Thessaly, where the author carried out extensive fieldwork, while revisiting known sites to re-evaluate previous claims or in the framework of survey projects in which he participated. Results from those zoomed-in examinations include new finds from the site of Kokkinopilos, Epirus and a re-appraisal of its significance for elucidating the early Palaeolithic of Greece. The revisit of site FS 30 at Rodia in Thessaly raises some doubts on the contextual data with which the lithic material is associated; it also suggests, however, a higher age for the local outcrops of fluvial gravels, underlining the potential of the Thessalian landscape for yielding Early Pleistocene archaeological evidence. In chapter five, the results from fieldwork in Macedonia (Aliakmon Project) and Zakynthos (Zakynthos Archaeology Project) are assessed and it is shown that the scarcity or total lack of stratified material is mostly due to geological biases, rather than research-related issues.

Chapter six explores the Quaternary landscape evolution and the degree to which geomorphic processes influenced the preservation of the Greek early Pleis-

tocene archaeological record on the landscape-scale. The interrelationships between vegetation, lithology, soils, topography and land use are examined against the background of an intense tectonic activity and a markedly seasonal climate. A slope map of Greece is used as a morphological measure to assess archaeological potential for preservation and recovery as a function of surface stability. Assessments of the effects of landscape instability upon archaeological context and visibility are shown to find support from a hypothetical classification of the landscape according to a nine-unit land-surface model. Overall, these analyses explain why the Greek Lower Palaeolithic record is scanty and why artefacts are rarely found in buried deposits. Moreover, it is argued that the fragmented nature of both the geological and the archaeological record before around MIS 6 is not a coincidence: it reflects an eco-geomorphic system dynamic and unstable enough to have prevented adequate preservation of landforms and associated archaeological material before the last interglacial-glacial cycle.

A synthesis of the results is presented in chapter seven. Here it is emphasized that only a very small proportion of the Greek Lower Palaeolithic record survived to the present. Particularly, it is argued that the areas which would have constituted ideal habitats for hominins and places with a great potential for high-quality preservation are now submerged by the sea. A conceptual geoarchaeological model is elaborated to explain the current status of the Greek record in comparison to the records from the Iberian and Italian peninsulas. According to this model, well-preserved and archaeologically visible Lower Palaeolithic sites occur in basin settings, which retained their role as 'sediment receivers' for most of the Early and Middle Pleistocene and were inverted into positive topographic features ('sediment producers') during the Late Pleistocene. The key explanatory factor is the timing of uplift and the duration and intensity of erosion accompanying the inversion of basins. In contrast to Iberia and Italy, an 'advantageous timing of uplift' (*i.e.* in the Late Pleistocene) was rather exceptional for the lowlands of Greece; most basins were affected by uplift already in the Early and Middle Pleistocene. Finally, the most promising locations for future Lower Palaeolithic investigations in Greece are suggested. The need for further research in the Aegean region is highlighted, whereas atten-

tion is drawn to mainland depressions with high prospects for yielding Early and Middle Pleistocene archaeological material, such as the basins of Megalopolis and Mygdonia.

This study shows that the poor record of the Lower Palaeolithic of Greece should be interpreted as the result of the biasing and destructive effects of Quaternary geomorphic processes and not as an indication of a former absence of hominins. Arguably, similar investigations are required before interpreting extant distribution patterns of early human presence, at least as regards areas of tectonically active settings and intense landscape dynamics.

Dutch Summary

In discussies over de vroege migraties van hominiden en de vroegste bewoning van Europa speelt het Middellandse Zeegebied een centrale rol, omdat dit gebied significant vroeger door hominiden bewoond lijkt dan meer noordelijke streken. Griekenland was waarschijnlijk, samen met andere delen van het zuidoosten van het Middellandse Zeegebied en de Balkan, een brongebied van waaruit grote delen van Eurazië gekoloniseerd zijn. Griekenland fungeerde mogelijk ook als *refugium* van waaruit hominiden herhaaldelijk hun verspreidingsgebied uitbreidden naar andere delen van Europa waar permanente bewoning door frequente klimaatsverslechteringen niet mogelijk was. De consensus in de paleoantropologische gemeenschap is dan ook dat Griekenland tijdens het vroeg-paleolithicum bewoond moet zijn geweest, zeker gezien het feit dat mensachtigen aanwezig waren in naburige gebieden die gekenmerkt worden door soortgelijke landschappelijke omstandigheden. Echter, in contrast met overvloedig bewijs voor bewoning van opgegraven vindplaatsen in het grootste deel van het Middellandse Zeegebied, zijn vroeg-paleolithische vondsten in Griekenland zeldzaam. Het meest voorkomende materiaal betreft oppervlakte vondsten, slechts gedateerd aan de hand van een veronderstelde archaïsche morfologie en op basis van - vaak zwakke - stratigrafische correlaties.

Dit onderzoek gaat in op de achtergrond van de schaarste aan vroeg-paleolithische vondsten in Griekenland en neemt daarbij de geoarcheologie als leidraad. Het uiteindelijke doel van het onderzoek is bij te dragen aan de kennis over de vroeg-paleolithische bewoning van Griekenland. Daartoe is een drievoudige aanpak gekozen. In het eerste deel van de studie wordt de huidige stand van zaken met betrekking tot het archeologisch bestand geïnventariseerd. Het tweede deel probeert het beeld dat uit deze stand van zaken voortkomt te interpreteren. Het derde gedeelte poogt voorspellingen te doen voor toekomstig onder-

zoek naar de vroeg-paleolithische bewoning van Griekenland.

Om de Griekse *record* op waarde te kunnen schatten wordt eerst een overzicht gegeven van de bredere context van de vroeg-paleolithische bewoning van Griekenland. In hoofdstuk 2 worden de belangrijkste aspecten van het vroeg-paleolithicum in het algemeen besproken, met een nadruk op onderwerpen die gerelateerd zijn aan migraties van vroege mensachtigen en de mogelijke rol van Griekenland daarin. Hoofdstuk 3 behandelt de informatie van de best bestudeerde vindplaatsen in het Middellandse Zeegebied. Dit overzicht concentreert zich op de geomorfologische context van vindplaatsen, de typo-technologische gegevens van de assemblages stenen werktuigen en de beschikbare chronologische informatie. Tegen deze achtergrond zullen vervolgens de Griekse data geëvalueerd worden.

In hoofdstuk 4 worden alle Griekse vindplaatsen en geïsoleerde artefacten die aan het vroeg-paleolithicum toegeschreven zijn aan een kritische analyse onderworpen. De analyse concentreert zich op het karakter van de gevonden artefacten, de depositionele context, de datering en de argumenten om de vondsten aan het vroeg-paleolithicum toe te schrijven. Regionaal ligt de nadruk op de provincies Epirus en Thessalië, waar de auteur veel veldwerk uitvoerde op bekende vindplaatsen, teneinde de interpretatie van de vondsten te evalueren. Verder nam de auteur deel aan survey-projecten die ten doel hadden nieuwe vindplaatsen in kaart te brengen. De resultaten van het veldonderzoek omvatten onder andere nieuwe vondsten van de vindplaats Kokkinopilos (Epirus) en een herwaardering van het belang van deze vindplaats. Het nieuwe onderzoek van de vindplaats FS 30 te Rodia in Thessalië leidde tot twijfels over de context van het vondstmateriaal; de daar daggomende riviergronden blijken echter ook ouder te

kunnen zijn dan tot dusver aangenomen. Dit laatste versterkt het potentiële belang van Thessalië voor het onderzoek naar vroeg-pleistocene archeologische voorkomens. In hoofdstuk 5 worden de resultaten van veldwerk in Macedonië (Aliakmon Project) en Zakynthos (Zakynthos Archaeology Project) beoordeeld. In dit hoofdstuk wordt aangetoond dat het ontbreken van vondsten in stratigrafische context vooral toegeschreven dient te worden aan vertekende geologische factoren.

In hoofdstuk 6 wordt de evolutie van Kwartaire landschappen en de invloed van geomorfologische processen op de staat van het Griekse vroeg-pleistocene archeologische bestand op landschappelijk niveau besproken. De complexe relaties tussen vegetatie, lithologie, bodems, topografie en landgebruik worden geëvalueerd tegen de achtergrond van onze kennis over de intense tektonische activiteit en de sterke seizoensmatige klimaatwisselingen die Griekenland kenmerken. Een kaart waarop de hellingshoeken van het landschap aangegeven zijn wordt als morfologische afgeleide gebruikt, op basis waarvan het archeologische potentieel van een gebied met betrekking tot zowel behoud als herkenning van archeologische materialen geïnventariseerd wordt. Het Griekse landschap wordt ingedeeld in een model dat de stabiliteit van het landoppervlak in kaart brengt. Dit model ondersteunt voorspellingen over de invloed van de instabiliteit van landoppervlaktes op de archeologische context en de archeologische zichtbaarheid van vroeg-paleolithische vondsten. De in dit hoofdstuk uitgevoerde analyses laten zien waarom vroeg-paleolithische vondsten in Griekenland zo schaars zijn en vrijwel nooit in stratigrafische context aangetroffen worden. Daarbij wordt betoogd dat het fragmentarische karakter van het geologische en archeologische bestand daterend vóór MIS 6 geen toevallige situatie is, maar het resultaat van een eco-geomorfologisch systeem dat zo instabiel en dynamisch was dat het het behoud van landschappen en de daarmee geassocieerde archeologische voorkomens belette.

In hoofdstuk 7 worden de gegevens van de voorgaande hoofdstukken in samenhang geanalyseerd. Het feit dat slechts een klein gedeelte van het Griekse vroeg-paleolithische bestand behouden gebleven is wordt benadrukt. Verder wordt betoogd dat gebieden die geschikte habitats voor mensachtigen én goede kansen voor het behoud van archeologische materialen boden nu door de Middellandse Zee overstroomd zijn. Een geoarcheologisch model dat de magere status van het Griekse bestand vergeleken met de bestanden uit Italië en het Iberische schiereiland verklaart wordt besproken. Dit model stelt dat goed bewaard gebleven, archeologisch zichtbare vroeg-paleolithische vindplaatsen voorkomen in sedimentaire bekkens die gedurende het grootste deel van het Vroeg- en Midden-Pleistoceen sedimenten bleven ontvangen, maar tijdens het Laat-Pleistoceen door geologische opheffing veranderden in sedimentproducerende gebieden. Het moment en de duur van opheffing, alsmede de intensiteit van de erosie spelen een sleutelrol in het aantreffen van goed bewaarde vroeg-paleolithische materialen. In tegenstelling tot de situatie in Italië en op het Iberisch schiereiland vond in Griekenland slechts zelden opheffing op een gunstig moment plaats; de meeste sedimentaire basins werden al gedurende het Vroeg- en Midden-Pleistoceen aan opheffing onderworpen. Tenslotte worden in dit hoofdstuk de meest veelbelovende gebieden voor onderzoek naar de vroeg-paleolithische bewoning van Griekenland gesuggereerd. Het belang van nader onderzoek in de Aegeïsche regio wordt benadrukt. Depressies op het vasteland zoals de bekkens van Megalopolis en Mygdonia bieden voor zulk onderzoek goede vooruitzichten.

Dit onderzoek toont aan dat het beperkte archeologische bestand van de vroeg- paleolithische bewoning van Griekenland geïnterpreteerd dient te worden als het gevolg van vertekende en destructieve geomorfologische processen in het Kwartair en niet als een indicatie van de afwezigheid van homininen. Gelijkaardig onderzoek in tektonisch en landschappelijk actieve gebieden zou plaats moeten vinden om de globale verspreidingspatronen van vroege mensachtigen beter te begrijpen.

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Appendix I: Photographs, maps and graphs from fieldwork in Epirus: Kokkinopilos, Ayia, Karvounari, Morphi

Appendix II: Photographs, maps and graphs from fieldwork in Thessaly: exposed deposits of river terraces ('upper' and 'lower' Hochterrasse, Niederterrasse); exposed fluvial deposits at the area of Rodia; site FS 30

The Appendices can be found at: www.lup.nl/tourlouloukis

Abbreviations and Notes

App.	Appendix
asl	above sea level
BP	Before Present (1950)
ka	kilo annum, thousands of years BP; it represents events in time
kyr	thousands of years; it denotes duration (intervals of time)
Ma	Mega annum, millions of years BP; as with 'ka', it represents events in time
myr	millions of years; as with 'kyr', it denotes duration (intervals of time)
MIS	Marine Isotope Stage

1. For the chronological division of the Pleistocene, the geochronological nomenclature is used in this study: 'Early', 'Middle' and 'Late' Pleistocene [for a recent discussion on the dual nomenclature that arises from the traditional distinction between time (geochronology) and time-rock (chronostratigraphy), see Head, M. and Xavier, F. 2010 *The GSSP Concept – Report of the International Commission on Stratigraphy Workshop, Prague, May 31-June 3, 2010*, and references therein]. When these forms are used with lower-cased initials ('early', 'middle' and 'late' Pleistocene), it is implied that, either the boundaries of the inferred particular time-slice are not well-resolved, or these boundaries transgress those of the formal Ages/Stages. In all cases, these informal forms are quoted as they appear in the original text of the citation. For instance, Schattner (2010) uses the term 'mid Pleistocene' or 'early-to-mid Pleistocene' to refer to a time-span ranging between about 1.0 and 0.7 Ma (*i.e.* a time-slice that would formally be included in the late Early-early Middle Pleistocene). Whenever numerical ages are used to clarify the reference to the informal age/stages, as in the example above, those ages are given, too; otherwise, context alone should be sufficient to denote the (alas, inadequate) correlation with the formal geochronological terms.
2. Due to practical reasons, it was not possible to include in this book all data collected during my fieldwork. I would encourage the interested reader to contact me at vag_tourloukis@yahoo.com for any questions regarding the sites mentioned in text or for more photographs, GPS-points, Munsell colour readings, etc.

Acknowledgements

For the completion of this work I owe gratitude to several scholars, colleagues and friends. I am particularly indebted to W. Roebroeks, P. Karkanas, E. Panagopoulou and C. Runnels for supervising my research and for sharing with me their valuable insights with regard to this project. Roebroeks never gave up encouraging me when I was ‘giving up’ with my struggle to *e.g.* understand fluvial geomorphology or palaeopedology; he followed closely the progress of my project, even when this included fieldwork at the Greek sites, where he accompanied me in 2008. It was Eleni Panagopoulou who first suggested to me Leiden University as the best choice for my graduate studies. While we were excavating at the site of Lakonis, she told me about “those two prominent scholars in Leiden that we can hardly pronounce their names” [*i.e.* Roebroeks and van Kolfschoten]; “this is where you need to go”, she said, and I am now glad that I followed her advice. If Eleni taught me almost everything about the Greek Palaeolithic, it is Panagiotis (Takis) Karkanas who has been guiding me in the field of Geoarchaeology; I would not have reached that far without his continuous support and endless ‘lecturing’ while doing fieldwork in various projects. I was introduced to the reading of landscape biographies from Takis, but my involvement in Landscape Archaeology and survey methodology bears the stamp of Curtis Runnels. In 2003, I participated in Runnels’ survey project in Kandia, Argolid, where we applied and tested a site location model. This was an invaluable experience and, back then, I would have never guessed that some years later I would be working on a geoarchaeological site location model for the early Palaeolithic. Professor Runnels has located the greatest number of Palaeolithic sites in Greece and if I have now some possible answers to the question of ‘how does he manage’, I owe a lot to his advices and constant support. I wish also to acknowledge the fact that Runnels provided me with unpublished data from his work in Greece.

Apart from my supervisors, I owe my sincere gratitude to a significant number of people; in fact so many, that I am sure I am forgetting here some of them (and for that matter, I hope they show some understanding). In no particular order, I would like to thank the following people:

T. van Kolfschoten, J. Bintliff and H. Kamermans for reviewing my thesis and suggesting important literature.

K. Harvati and E. Panagopoulou for recruiting me in the Aliakmon Project and for providing me published and unpublished data related to the project. Similarly, I am indebted to G.J. van Wijngaarden (Zakynthos Archaeology Project) for granting me access and permission to use data that are not yet fully published and/or are due to be published, but also for helping me in various ways, when I was doing fieldwork in Zakynthos as a member of his survey team. G. Riginos, K. Zachos, G. Toufexis and all my colleagues in the local departments of the Archaeological Service in Epirus and Thessaly for helping me with fieldwork permits, logistical support and the struggle against the monster of bureaucracy. P. Karkanas, E. Adam, O. Palli and especially Nick Thompson for their remarkable assistance while I was doing fieldwork or studying collections of lithic material.

Prof. Dr. R. Caputo (University of Ferrara), for his in-depth teaching in tectonics and structural geology while doing fieldwork together in Thessaly and Zakynthos, and for reviewing my chapter on Thessaly, which was significantly improved after considering his remarks.

A. Athanassiou for reviewing this dissertation, providing thoughtful feedback and relevant literature, as well as for the ‘guided tour’ to the Megalopolis ba-

sin. D. van Hinsbergen for his thorough review of section 6.3 and H. van Essen for his important remarks on section 4.6 and the faunas of Thessaly.

J. Porck for her wonderful work with the figures of this book and H. Kamermans for his support in the process of publication; D. Sardelianos, V. Klinkenberg and M. Gkouma for the production of the slope map and their help with all GIS-related problems that I encountered; E. Dullaart for the compilation of SRTM data and T. Mast for the IT assistance; J. Wallinga and his associates at the Netherlands Center for Luminescence for all their efforts in dating sediments from Zakynthos and Kokkinopilos.

G. Koufos and the Laboratory of the University of Thessaloniki for providing the photograph of the Petralona cranium; V. Kapsimalis for the sea-level data; M. Skourtsos for teaching me geological cartography in Athens University; D. Papagianni for the discussions on the lithic material of Epirus; N. Ashton and M. Roberts for all their help in Franks House, when I studied some British and African Lower Palaeolithic assemblages; F. Kofidou and B. Garefalakis for their hospitality in Southampton and all their encouragement; S. Kuhn for showing me some unpublished material from Turkey; G. Koukis for mailing me important publications on slope processes; K. Kotsakis for his understanding as supervisor appointed by the State Scholarships Foundation.

I warmly thank my colleagues from the Human Origins Department of Leiden for reviewing significant parts of an earlier manuscript of this work, but also for the good times we shared together: (this time in alphabetical order) E. Croxall, A. Jagich, K. MacDonald and M. Sier, as well as A. Verpoorte, R. Corbey, M. Field and the rest of the teaching staff in the Faculty of Archaeology, but also R. Manning for her constant support. I am indebted to Gerrit Dusseldorp for helping me in the last days of panic. I would also like to thank my colleagues from the survey teams of the Aliakmon and the Zakynthos projects for all their help in the field and the fun in the bars.

Perhaps I should have put my family and friends first in this list, but, on the other hand, those are the ones who will certainly not misunderstand me. They know: my respect and gratitude to them has nothing to do with kinship or any ethical manners. I would like to thank them for being there and for being close to me. Last but not least, I would like to thank Vicky for the hugs and understanding, Clara and Doug for their support, my comrades from 'the cynical house' for their solidarity and inspiration (especially during the hard times of suffocation in academia), and all friends and comrades engaged in social struggles in the Netherlands, Greece and worldwide.

Curriculum Vitae

Evangelos (Vangelis) Tourloukis was born in Athens on August 9th, 1976. In 2000, he graduated from the department of History and Archaeology at Athens University, with a major in Archaeology and History of Art (four-year studies); his thesis was entitled “Archaeological Methodology and Interpretation” and was supervised by Prof. Chr. Doumas. In 2002 he worked for the Greek Archaeological Service (8th Department of Prehistoric and Classical Antiquities, Epirus) and in 2003-2004 he successfully completed a Master of Arts program (*cum laude*) in European Prehistoric Archaeology at Leiden University, with a specialization in the Palaeolithic of the Mediterranean and a thesis supervised by professors W. Roebroeks and T. van Kolfschoten. In 2004 he succeeded in written examinations and was awarded with a grant from the State Scholarships Foundation of

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Vangelis has worked as field archaeologist in numerous excavations and survey projects in Greece. Most recently, he was field assistant and carried out typotechnological analyses of Palaeolithic artefacts in the Aliakmon survey project, the Thesprotia Expedition, the Kandia Survey (Argolid), and the Zakynthos Archaeology Project. In 2002 he took part in the excavation of the Palaeolithic cave of Kalamakia and since that year he has been a constant member of the excavation team working at the cave site of Lakonis. Apart from his main involvement in Palaeolithic studies and Geoarchaeology, his key research interests include Quaternary geomorphology, landscape archaeology, palaeoanthropology and methodology of survey projects.